LEGO DACTA®

Control System

Integrating Math and Science for Upper Elementary

Teacher Guide

9702
Book 2

LEGO dacta®

The *educational* division of The LEGO® Group

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Welcome to Control System!

LEGO DACTA® Control System provides middle school teachers with hands-on learning activities to supplement regular science instruction in the areas of:

- Motion
- Work, power, and energy
- Electricity

Activities also include many connections to the mathematics curriculum, with suggested extensions to technology, language arts, and social studies.

The Control System activities are based on the Simple Control building set (item #9702) used with a light sensor, an angle sensor, and the Control Lab computer software and interface box.

The LEGO DACTA Control System instructional material consists of the following items.

- *LEGO DACTA Control System Setup Guide* - setup instructions and introductory activities.
- *LEGO DACTA Control System Teacher Guide* - instructional units and student activities for use after the Setup Guide.
- *LEGO DACTA Control System Quick Reference Guide* - summary of most-often-used software commands and other helpful information.
- *LEGO DACTA Control Lab Reference Guide* - detailed information about the Control Lab software.

► Before using this book, make sure that:

___ You have installed the LEGO DACTA Control Lab software and hardware on your computer. (See pages 2 - 4 of the *LEGO DACTA Control System Setup Guide.*)

___ Your students have completed the Control System introductory explorations. (See pages 5 - 25 of the *LEGO DACTA Control System Setup Guide.*)

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Overview of Control System Activities

Students learn by doing. To facilitate this process, these activities in this teacher guide are divided into three different types.

1. Exploration - an introduction to materials and concepts.

Students encountering new materials, equipment, or concepts need to get familiar with them. Through informal exploration, students are introduced to the Control System materials and to science and mathematics concepts.

2. Investigation - an encounter with organized learning.

Once familiar with the materials and concepts, students are ready for a more formal mode of learning to learn specific concepts and develop skills. Students follow instructions to build a model and then investigate its behavior, as in typical science experiments.

3. Invention - an opportunity for problem solving.

After students learn new concepts and develop new skills with materials, they are motivated to *apply* what they have learned to solve problems. They become enthusiastic inventors, applying their knowledge and skills as they create, build, and test devices of their own design. The ultimate level is reached when students create their own problem challenges and set about solving them.

The units which follow contain one or more of each type of activity. Teacher pages include details and helpful information to prepare and present the activities. Student handout copymasters start on page 53.

Because of the flexibility of the activity types, you can use the Control System materials in many different ways. Sequentially, the activities present important concepts that build upon each other. Activity types can also be matched to individual student learning styles and ability levels.

Additionally, you can use the materials in a more discovery-oriented approach by preparing student project files on disk in advance. Follow the instructions closely on the student handouts to type procedures in the Procedures Page and to create various objects (buttons, monitors, etc.) on the Page1 project page. Save each handout file separately. This technique may help students focus more on the actual science and mathematics concepts and less on the computer programming.

Questions and Answers

✏ **Teacher note:**

For each activity in this booklet, we suggest that you photocopy the student handout from the appendix and refer to it as you read through the teacher notes.

Q. How do I prepare for teaching with Control System materials?

A. First, work through the exploration activities in the *LEGO DACTA® Control System Setup Guide.* Then you are ready to select activities from among the units in this booklet.

Q. Do I have to complete all of the activities in this booklet?

A. No. Each activity is designed to stand on its own, but the activities within a unit generally build upon each other. Select the unit activities which meet your needs and survey the other activities to determine if any additional information or skills need to be included. Activities in Unit I (Motion) help develop computer skills in writing procedures and setting up monitors, graphs, buttons, and other objects on the software project page.

Q. Do I have to build each model in order to prepare my lessons?

A. It is a good idea to build them, but it is not absolutely necessary. Building instructions and suggestions are provided for your students. You should consider building the exploration models, particularly if you are preparing student project files on disk in advance. You can verify your project files and familiarize yourself with how the models operate with the software.

Q. How long is each lesson?

A. Each activity is designed for one to two class periods. The actual time required depends on several factors, including student experience with computers and familiarity with LEGO® building elements, as well as your own teaching objectives. The student handouts include numbered steps for flexibility in assignments. For example, students could stop at step 9 today and begin at step 10 at the next class meeting.

Q. Can I do more than teach just science with these materials?

A. Of course! Mathematics activities and optional interdisciplinary extension suggestions are provided in each unit for technology education, social studies, and language arts.

Q. What should I do if some building elements are broken or do not function?

A. If you require any kind of service for your Control System components, write to Susan Williams, Consumer Affairs, LEGO Systems, Inc., PO Box 1138, Enfield, CT 06083-1138, or call (203) 763-3211.

What Do Students Learn?

The grids shown on this page summarize the science and mathematics concepts that students can learn in each Control System unit.

Science Concepts	Motion Unit	Work, Power, & Energy Unit	Electricity Unit
Distance	x	x	
Time	x	x	x
Average speed	x	x	
Force	x	x	
Work		x	
Power		x	
Energy		x	x
Electricity generation			x

Science Process Skills	Motion Unit	Work, Power, & Energy Unit	Electricity Unit
Measuring	x	x	
Collecting data	x	x	x
Comparing	x	x	x
Predicting	x	x	x
Hypothesizing	x	x	x

Mathematics	Motion Unit	Work, Power, & Energy Unit	Electricity Unit
Problem solving	x	x	x
Communication	x	x	x
Reasoning	x	x	
Connections	x	x	x
Computation	x	x	
Estimation	x	x	
Measurement	x	x	
Graphing	x	x	x
Pattern recognition	x	x	x

Mathematics concepts are from *Curriculum and Evaluation Standards for School Mathematics* published by the National Council of Teachers of Mathematics.

Assessment Ideas

Using a wide variety of assessments will provide a broader picture of student progress. Here are a few examples.

Assessment area	Possible assessment methods
Cognitive area Intellectual skills and knowledge	• Pencil and paper tests • Student projects and reports • Observational checklists • Student discussions
Affective area Changes in student interests, values, and attitudes	• Surveys • Journal entries • Student discussions
Psychomotor area Manipulative skills	• Building challenges • Frequent teacher observation

In discussing activities with students, use several different types of questions to assess student understanding at various levels of thinking, corresponding to the levels of Bloom's *Taxonomy of Educational Objectives.*

Thinking Skill	Sample Questions
Recalling	What is the definition of average speed?
Understanding	How does your LEGO® vehicle demonstrate speed?
Applying	How could you make a faster vehicle?
Analyzing	How are the more powerful winches alike?
Synthesizing	In what other ways will these elements fit together?
Evaluating	Which device has the most effective design?

You may wish to make a checklist of several of the following science process and inquiry skills to track individual student progress.

- ❐ **Observing** the behavior of objects and their interactions
- ❐ **Describing** clearly what is observed
- ❐ **Identifying** variables in an investigation
- ❐ **Measuring** length and time accurately
- ❐ **Recognizing** space and time relationships
- ❐ **Classifying** objects or concepts into categories
- ❐ **Building** and using models to investigate and experiment
- ❐ **Collecting** and **interpreting** data from investigations
- ❐ **Comparing** and **contrasting** information from different sources
- ❐ **Constructing** personal theories from data
- ❐ **Predicting** the behavior of an object
- ❐ **Hypothesizing** a possible relationship between two variables
- ❐ **Experimenting** to confirm or disprove a hypothesis
- ❐ **Questioning** or pondering curiously a supposition
- ❐ **Inferring** or deducing facts from available information
- ❐ **Formulating** and solving problems
- ❐ **Replicating** an experiment or confirming a law

Other assessment ideas to consider include the following.

- A journal or "Inventor's Notebook" could be part of the assessment for each team of students or each individual student. The journal could include detailed reports, drawings, data tables, and summaries of results.

- Question individual students randomly during building activities to determine if they understand operational definitions and concepts.

- Consider performance-based assessments in which students are required to demonstrate their accomplishments.

- Student team presentations of their projects often provide clear indications of the level of understanding. Presentations could take the form of written or oral reports, videotaped reports, or "newscasts."

General Hints and Tips

1. Using "friendly" manipulatives such as LEGO® building elements can provide students with enjoyable learning experiences. Don't forget to provide for an element of fun.

2. Have students work in teams of two or three to encourage cooperative learning.

3. Encourage students to make use of calculators.

4. Include your own science measuring tools and equipment as much as possible.

5. As with all science materials, be safety conscious.

6. Provide additional materials such as cardboard, tape, paper clips, and markers.

7. The plans in this guide are intended as suggestions. Modify them to suit your particular needs.

8. Number your LEGO DACTA® Simple Control building sets (item #9702) so that student teams work with the same set during each class meeting.

9. Encourage students to store the LEGO building elements in the appropriate set compartments after each activity.

References

Bloom, Benjamin, ed. *Taxonomy of Educational Objectives, Handbook I: Cognitive Domain.* New York: David McKay, 1956.

Caney, Steven. *Steven Caney's Invention Book.* New York: Workman Publishing Co., Inc., 1985.

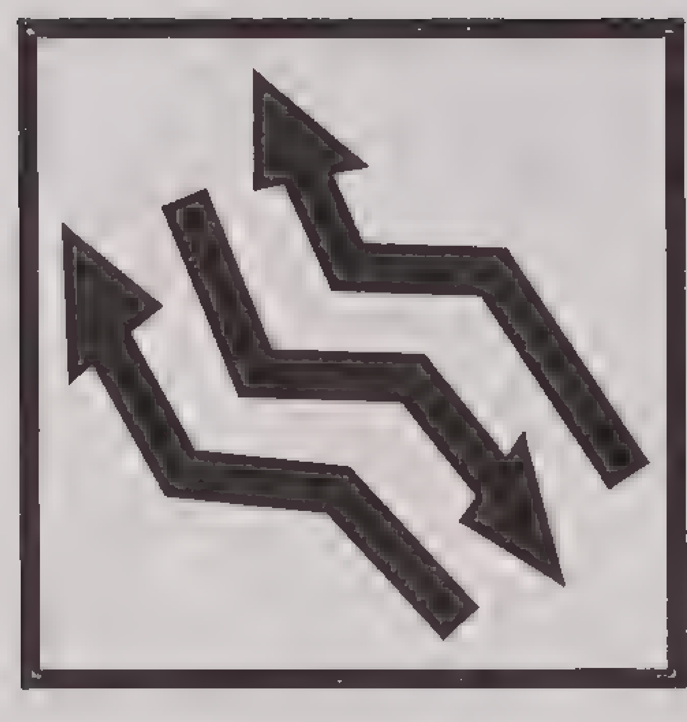
Laithwarte, Eric. *Force: The Power Behind Movement.* New York: Franklin Watts, 1986.

Macaulay, David. *The Way Things Work.* Boston: Houghton Mifflin, 1988.

Marzano, Robert J. *A Different Kind of Classroom.* Alexandria, VA: ASCD, 1992.

VanCleave, Janice. *Physics for Every Kid.* New York: John Wiley & Sons, Inc., 1991.

UNIT I
Let's Get Moving: Motion as a Study of Change



Objectives

The purpose of this unit is to introduce students to the concepts of linear motion, computer control, and feedback through the Control System activities and the Control Lab software and interface box.

At the end of this unit, each student will be able to:

- Define and measure distance and time with:
  - ordinary tools (meter sticks and stopwatches)
  - computer-based tools (information from light and angle sensors)
- Define and calculate average speed
- Use the computer as a tool appropriately for detecting changes in distance and time and using this information for determining motion
- Write simple procedures (computer programs)
- Set up a project page on the computer, with graphs, text, clip art, monitors, buttons, and sliders

Activity Listing

	Exploration 1	Write simple computer procedures
	Exploration 2	Explore distance with a trundle wheel
	Exploration 3	Explore personal reaction time
	Exploration 4	Explore the average speed of a motorized car
	Investigation 1	Determine the average speed of a motorized vehicle or a walking robot
	Invention 1	Build a motorized vehicle with a high average speed

Additional Materials Needed

- Meter sticks, yardsticks, or rulers
- Stopwatches
- Calculators

Background Information

Distance, Time, and Speed

Being able to describe the motion of an object in terms of change is one of the most fundamental skills in physical science and physics. This unit allows students to develop operational definitions for distance, time, and speed in terms of changing position over a period of time.

In general, distance refers to how far an object moves, or how much its position changes. Time is the period between two events, such as the time between a runner leaving the start line and reaching the finish line in a race.

Speed is an indication of the change in position of an object, or the distance an object moves, in a certain amount of time. To calculate the speed of an object, divide the distance the object travels by the time taken to travel that distance.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

The units of speed depend on the measurement units of the distance and time. For example, if the distance is measured in centimeters and the time is measured in seconds, then the speed is calculated in centimeters per second, because the distance in centimeters is divided by the time in seconds.

Typical units of speed include centimeters per second (cm/s), meters per second (m/s), kilometers per hour (km/hr), feet per second (ft/s), and miles per hour (mi/hr). For example, a LEGO® model that travels 20 centimeters in 5 seconds has a speed of 20 / 5 = 4 centimeters per second, or 4 cm/s.

Because of friction and other factors, few objects on earth travel at a constant speed. When we divide a distance by the time to travel that distance, we are calculating what we call the *average speed* for an object. The average speed takes into account any changes in an object's motion during the time of travel. All calculations in this unit produce an average speed.

Light blue booklet from Simple Control building set (item #9702)

Hints, Tips, & Tools

1. Metric units of linear measurement are recommended for science activities. However, the activities in this instructional unit can be performed with customary units (i.e., inches, feet, yards) as well.

2. Be sure that you and your students are familiar with the Control Lab software and interface box before starting this unit. Refer to the *LEGO DACTA® Control System Setup Guide* for additional details.

3. The drawings on pages 4 and 5 of the light blue booklet in the Simple Control building set (item #9702) are useful introductory building projects for students not familiar with LEGO® building elements.

4. The *LEGO DACTA® Control System Quick Reference Guide* might be a handy source of software information for your students.

5. The instructional steps on each student handout are designed to be carried out in sequence. Help students understand the importance of working through the handouts carefully and sequentially instead of skipping around. After they learn the skills on which the handouts focus, students can work on their own.

6. Some of the activities in this unit might require more than one class period.

Motion Exploration 1
A Matter of Procedure

Goal - Write simple procedures (computer programs) to control the motor, lamp, and sound element.

Specific Background Information

You cannot make use of a computer unless you can communicate with it. Your students have already begun learning how to do this in the *LEGO DACTA Control System Setup Guide* explorations. In particular, they have communicated with the computer by:

- Using a mouse to point, click, and drag.
- Using a keyboard to type commands.

In this exploration, students will learn how to write simple computer programs, or *procedures*, as another way of communicating with the computer. A procedure is simply a way of gathering several commands together. Procedures are used as building blocks to more complex programs, just as students use individual LEGO® bricks to build more complex structures.

Students will use what they learn in this exploration to write simple procedures for other activities in this guide.

What To Do

Divide students into teams of two or three. Assign each team to a computer equipped with the Control System materials:

- Control Lab software - installed on hard disk
- Interface box, cable, and transformer - connected to computer
- Simple Control building set (item #9702)

Your students should have already worked through the *LEGO DACTA Control System Setup Guide* to learn about the Control Lab software and the sensors to be used with Control System, and how to use the software Setup Page and commands in the Command Center.

Mention to students the importance of typing carefully. Having a space in the wrong place can "confuse" the computer software.

Distribute Handout 1 to the student teams. (See copymaster on page 54.)

Handout Tips

In step 6 of the handout, the word after `to` is the procedure name. This name, `turn`, becomes a command. Some students might be surprised that the computer does not carry out instructions as they are typed into the Procedures Page. This is because the instructions on the Procedures Page are "remembered" by the computer and are not carried out until requested by typing the procedure name in the Command Center.

In step 8 , pressing Return or Enter to make space between procedures is a good programming technique. This makes it easier to find separate procedures on the Procedures Page.

In step 9, the `shine` procedure should look like this.

```
to shine
talkto "lampb
onfor 20
end
```

In step 10, the `beep` procedure should look like this.

```
to beep
talkto "soundc
onfor 30
end
```

In step 11, help students understand they are using procedure names as commands inside the action procedure. This is a powerful demonstration of how procedures can be used as building blocks in other procedures.

Programming Tips

When students write their own procedures, they should:

1. Go to the Procedures Page.

2. Start all procedures with the word `to` followed by a procedure name of their choice on the same line.

3. Type the procedure instructions (commands) beneath the first line.

4. Type `end` by itself on the last line of the procedure.

A procedure name consists of one word, such as `turn`. Students can join two words together to make a more descriptive procedure name, such as `moveforward`. A technique to improve readability is to separate the words with a period, such as in `move.forward`.

Interdisciplinary Extensions

Mathematics

Challenge students to explore procedures that calculate various results using the `show` command. Here is an example. Note that there is a space on *each side* of the "*" (multiplication) and "/" (division) signs.

```
to result
show 5 * 3 / 9
end
```

Encourage students to explore the concept of variables in a procedure. For example, they could write a procedure with a time variable so that they could change the length of time the motor is on. In the `spin` procedure below, the variable `:time` (an *input variable*) holds a place for a number supplied by the user. Type `spin 60` in the Command Center and the motor goes on for 6 seconds.

```
to spin :time
talkto "motora
onfor :time
end
```

Extra: If students change the third line of the procedure to `onfor :time * 10`, the input variable of `:time` can be in seconds. This means that, if students type `spin 6` in the Command Center, the procedure would multiply 6 times 10 and run `onfor 60`.

Technology

In robotics, the sequence of commands is often important. Students can experiment with sequences of procedures, such as `turn beep shine`. They can also use the `repeat` command for repeating sequences a certain number of times. In the example below, the sequence of `[beep turn]` is `repeat`ed 5 times.

```
repeat 5 [beep turn]
```

Make sure students use the left and right square brackets [ ] with the `repeat` command, and not { } or ( ).

To process a sequence forever, students could use the `forever` command.

```
forever [turn shine]
```

To stop all the sequences being processed with the `forever` command, use the `stopall` command.

Language Arts

Ask students to discuss how poetry is like a computer program. Some poems have verses and a refrain. The verses are like individual procedures, while the refrain is like a repeated procedure. What other similarities can they find?

Because the names of the procedures can be chosen by the person writing them, perhaps students could use the software to learn words in a second language at the same time. For example, here is a procedure that will run the `on` command when the corresponding Spanish word `encender` is typed. (Use `apagar` as the name of a procedure for the `off` command.)

```
to encender
on
end
```

Students can type other text on the Procedures Page in addition to procedures; that is, it can serve as a sort of electronic notebook. Several may be interested in exploring this option.

Social Studies

The history of computer programming includes many computer languages, many of which are already obsolete. Others, such as FORTRAN, BASIC, and Logo are widely used today. Ask students to research computer programming and identify several early computer languages. Construct a time line to show important computer events.

Motion Exploration 2 Trundle On

Goal - Measure distance with a trundle using an angle sensor and computer feedback.

Additional Materials Needed

- 1 meter stick, yardstick, or ruler per group
- 1 calculator per group (optional)

Specific Background Information

Have you ever seen someone measuring a distance using a wheel? Coaches use a trundle to measure athletic fields. Insurance agents and police officers use trundles to measure distances at auto accidents.

A trundle is a wheel with a known circumference (e.g., 1 meter) marked off in smaller units of length (e.g., centimeters). By counting the number of revolutions the wheel turns while rolling between two points as you walk, and knowing the wheel circumference, you can figure out the distance you have walked. This is much more convenient than trying to use a tape measure.

What To Do

Divide students into teams of two or three. Assign each team to a computer equipped with the Control System materials:

- Control Lab software - installed on hard disk
- Interface box, cable, and transformer - connected to computer
- Simple Control building set (item #9702)
- One angle sensor

Ask students in each team to place a thick rubber band o-ring (as a tire) on a pulley wheel. Challenge students to determine the circumference of their wheels. They could explore many different ways to do this. Some might measure the diameter and multiply by the value of pi or 3.14159. Others might simply make a mark on the tire, place the mark over the edge of a piece of paper, roll the wheel one complete revolution, and measure the distance. Still others might wrap a piece of cellophane tape or paper around the wheel, make a couple of marks, unwrap the tape, and measure the distance between marks. Typical circumference values are around 9.5 cm or 3 3/4 in.

Distribute Handout 2 to student teams. (See copymaster on page 57.)

Handout Tips

In step 1 of the handout, students build a trundle based on the angle sensor. In the suggested model shown in the drawing, the gear on the wheel axle and the meshing gear on the angle sensor each have 24 teeth. When the wheels turn once, the axle in the angle sensor turns once also.

In step 4, students display the angle sensor dialog box by double-clicking on the angle sensor icon on output port 7. A dialog box provides a way to modify some aspect of an object such as, in this case, the reading of the angle sensor on output port 7. Each icon on the Setup Page has a similar dialog box.

In step 6, rolling the trundle in one direction will cause the angle sensor number to increase. Rolling it in the opposite direction makes the number decrease. If the number decreases past zero, negative numbers are displayed. Results are usually around 16 counts for one revolution and around 32 or 33 counts for 20 centimeters with models using the same size of gears. (If students use a 24-tooth gear on the wheel axle and a meshing 8-tooth gear on the angle sensor instead, the angle sensor gear will turn three times for each turn of the wheel gear. This produces about 100 counts per 20 centimeters.)

In step 8, the computer automatically names the first monitor created as `monitor1`. The four small black boxes at the corners indicate that the monitor is "selected." This means that the monitor can be moved around the screen. Students can move a selected monitor by dragging it with the mouse. When the mouse button is clicked on another portion of the screen, the four small black boxes disappear, indicating that the monitor is "deselected." To select a monitor at a later time, students hold down the Shift key and click once on the monitor.

In step 9, if the angle sensor does not appear as an option when students click and hold on f(x) in the Show: box, it probably means that the angle sensor icon has not been dragged to output port 7 on the Setup Page.

In step 13, the `resetrotation 7` command resets the reading of the angle sensor connected to input port 7. Make sure students put a space between `resetrotation` and `7`.

In step 15, students are finding a number (called a scale factor) by which to multiply the angle sensor reading to obtain the distance the trundle rolls. If the angle sensor reading is 16 after rolling a distance of 10

centimeters, for example, the scale factor is 10 / 16 = 0.625. Students can type `show 10 / 16` in the Command Center if they want the computer to calculate their scale factor instead of using a calculator.

In step 23, students explore the graphing capabilities of the Control Lab software. They graph the angle sensor reading along the y-axis and time in seconds along the x-axis.

Building Tips

All wheels should rotate freely. Any friction could cause the wheels to slide as they roll; this would affect the accuracy of the results.

Programming Tips

Talk students through the `trundle` procedure so that they know what each step does. Students type their scale factors in place of the blank.

```
to trundle
make "distance ___ * angle7 ——— multiplies scale factor by the angle sensor reading to calculate distance*
show sentence :distance [centimeters] — displays the value of the distance and units**
end
```

*The `make` command assigns a value to a variable. In this case, the result of the calculation of the scale factor multiplied by the angle sensor reading is assigned to the variable named distance. The software uses a single set of quotation marks (") to designate the *name* of an object or variable. In this case, `"distance` refers to the *name* of a variable called distance.

**In most of the procedures in this booklet, students will use `show sentence` to display calculated values and the corresponding units. `sentence` looks for two items to join together as a "sentence" which is printed by the `show` command. The software uses a colon (`:`) to designate the *value* of a variable. Here, `:distance` refers to the value calculated from `make "distance ___ * angle7`.

Students can remove buttons, monitors, and other objects from the Project Page by selecting them (Shift double-click) and pressing Delete (Macintosh) or Backspace (MS-DOS).

Students may want to set up monitors for values other than numbers from sensors. Students could select f(x) in the monitor dialog box and type in `0.6 * angle7` to show the distance in centimeters their trundle rolls, for example (assuming their centimeter scale factor is 0.6).

Students can print their procedures by going to the Procedures Page and then typing `printtext` in the Command Center.

Interdisciplinary Extensions

Mathematics

Have the students use their trundle and angle sensor readings to determine the perimeter of geometric figures, including squares, rectangles, circles, and irregular closed figures. (Students may find that they get inconsistent results when tracing curved lines. This is because one wheel or the other may have slipped. In this case, suggest that the students tilt the trundle so that only one wheel is rolling.)

Give students the opportunity to use their trundles to measure distances on a map. They will have to figure out how to incorporate the map scale into their calculations. For example, if the map scale is 5 miles to the inch, they would have to use their inch scaling factor to convert their trundle count to inches, then multiply the distance measured in inches by 5 miles.

Challenge students to interpret graphs produced by the rolling of a trundle wheel. Can they identify which way the trundle was rolled and estimate how far it was rolled, for example?

Technology

In transportation, it is important to be able to select the most efficient path for the delivery of materials and other goods. Use the trundle to measure distances on a highway map of the state. Look for examples that might simulate actual transportation decisions, such as choosing between a curving northeasterly "scenic route" and a section of interstate highways that run east and then north.

Technical performance reports for vehicles must be accurate. In order to determine the fuel consumption in miles per gallon, the testers must be able to measure the distance accurately. A common technique is to attach a calibrated trundle to the rear bumper of the test car. This trundle will also give information about the accuracy of the vehicle odometer. Ask students to find magazine articles about automobile tests that use a trundle.

Language Arts

Write a story of a journey from the point of view of a trundle.

Write dialog between a large trundle and a small one. On what points would they agree and disagree?

Social Studies

Discuss some of the ways distance was measured in the "old days." Informal measurements include how far one could travel in a day on foot or by horseback. More formal measurements include those made with surveying instruments.

Investigate the many different units of measurement from historical times. Units such as the foot, inch, furlong, cubit, fathom, rod, chain, meter, yard, mile, and league all have interesting histories. Have the students discuss why some of these units are still in use today and others are not. This could be an excellent research topic.

Motion Exploration 3
Time Flies

Goal - Students learn the need for computer-aided measurement by exploring human physical limitations in reaction time.

Additional Materials Needed

- 1 stopwatch per group

Specific Background Information

If you are trying to determine how long it takes an event to occur, what is the best way to proceed? Wall clocks have second hands, so they are good for timing events that take several minutes to occur. Events that happen in a few seconds are often timed using a stop watch. Modern stop watches are electronic and have no moving parts. Electronic models that can measure hundredths of seconds are more precise than older stop watches with gears and springs, which usually can measure only in tenths of seconds.

What are the human factors involved in timing an event? How long does it take a person to perceive that an event has occurred and then press a button to start or stop the watch? Is this period of time significant compared to the event being studied?

The purpose of this activity is to demonstrate that, in certain situations, human reaction time can be a significant factor in measuring time.

What To Do

Give students the opportunity to explore their reaction times with a stopwatch. One possible task is to see how long it takes to start and then stop the stopwatch. For most people, it generally takes 0.1 seconds or more. If you have a digital stopwatch that reads hundredths of a second you might be able to identify one or two "superstars" who can produce a time of 0.09 seconds or less.

Divide students into teams of two or three. Assign each team to a computer equipped with the Control System materials:

- Control Lab software - installed on hard disk
- Interface box, cable, and transformer - connected to computer
- Simple Control building set (item #9702)
- One light sensor

Student teams can explore their reaction times with computers. Ask students to follow the instructions on Handout 3. (See copymaster on page 62.)

Handout Tips

In step 4 of the handout, students will obtain readings up to 100 for very bright areas and readings less than 60 for darker areas.

In step 5, students must remember to hold down the Shift key and double-click the graph to display the graph dialog box.

In step 6, it is important that the students NOT place their fingers directly on the end of the sensor. This reflects some of the red light back into the sensor and may give an unrealistically high sensor reading.

In step 8, students may wish to connect the lamp to output port B instead. In this case, they will have to type `talkto "lampb on` in the Command Center (or in the `reaction` procedure in step 11) to turn on the lamp.

In step 9, the light sensor reading is likely to be 100 when it is facing the lamp. This configuration with a light beam shining into a light sensor is called a *photogate.* When attached to a computer, a photogate can be used to time events and to control motion.

In step 10, students should block the light to the sensor by putting their fingers or hand between the lamp and the sensor without touching the sensor. This usually produces sensor readings below 60.

In step 11, students should understand what the procedure does. For more details, see the Programming Tips section on the next page.

In step 12, students should understand that the procedure waits a random period of time and then simultaneously turns on the sound element and starts the timer. They are to block the light as quickly as possible after they hear the sound to stop the timer. The `reaction` procedure may need adjusting, depending on the light conditions. The number in the `waituntil` line should be greater than the light sensor value when the light is blocked.

In step 13, students might suggest starting with their hands placed closer to the light beam or practicing more.

In step 17, times of 0.5 seconds or less are possible, with hand speeds of 60 cm/sec or more.

In step 18, a *photogate timer* is simply a light beam that stops a clock when it is interrupted. In the next exploration, students will use a photogate timer to find the speed of motorized vehicles. Light sensors are also used to open doors, activate burglar alarms, and control robots.

Programming Tips

Here is an annotated listing of the `reaction` procedure from Handout 3. It is important to talk the students through the procedure so they understand what each line does.

```
to reaction
wait 30 + random 100 ------------------- waits a random period of time*
talkto "soundc on ---------------------- turns on the sound element
resett1 -------------------------------- restarts timer #1 from zero
waituntil [light8 < 60] ---------------- waits until the light sensor is covered
make "time timer1 / 10 ----------------- calculates reaction time in seconds**
show sentence :time [seconds] ---------- displays time value and units
off ------------------------------------ turns off the sound
end
```

*The `random 100` primitive reports a value from 0 to 99. If the random value is 0, the wait time is 30 + 0 = 30 tenths of a second, or 3 seconds. If the random value is 99, the wait time is 30 + 99 = 129 tenths of a second, or 12.9 seconds. The wait periods are randomly between 3 and 12.9 seconds long. See page 2.59 of the *LEGO DACTA Control Lab Reference Guide* for more information on `random`.

**The computer has four timers, each of which counts in units of tenths of seconds. This procedure uses timer #1. The `timer1 / 10` calculation divides the result of timer #1 by 10 to obtain seconds. See page 2.89 of the *LEGO DACTA Control Lab Reference Guide* for more information on `timer1`.

For a longer minimum time before the sound comes on, increase the value of 30 in the `wait` line of the `reaction` procedure. For example, `wait 50 + random 100` would wait a minimum of 5 seconds (50 tenths of a second) and a maximum of 14.9 seconds (5 seconds plus 99 tenths of a second).

To widen the range of possible wait times, increase the value of 100 in the `wait` line of the `reaction` procedure. For example, `wait 30 + random 200` would wait a minimum of 3 seconds and a maximum of 22.9 seconds.

Students can use the arrow keys or the mouse to move the cursor to commands already typed in the Command Center. Once the blinking cursor is on the desired line, they can run the commands on that line by pressing Return or Enter. They type `cc` if they want to clear the Command Center of all text.

Data Processing Tips

Students can examine the values of readings in the graph by clicking on the graphed line or curve. Readings are displayed above the graph.

If students want to clear their graph without starting the graphing action, they can type `clearcurve 1` in the Command Center.

Students may want to change the name or other characteristics of their graph. They can do so in the graph dialog box. To display the dialog box, hold down the Shift key and double-click the graph. Pages 1.24 through 1.29 in the *LEGO DACTA Control Lab Reference Guide* contain helpful information.

Interdisciplinary Extensions

Mathematics

The metric system is based on the number 10. Every unit is divided into ten smaller units or grouped with 9 units like itself to make the next larger unit. Time is the only measurement that has not been "metrified." Ask students to discuss possible reasons why time is not measured in metric units.

Have the students invent their own system for the metrification of time. They should display their system on a chart and be prepared to present it to the class. Allow the class to determine the most popular of all the systems in the class.

Technology

Have the students modify the `reaction` procedure to be a stopwatch by deleting `wait 30 + random 100` and use it to measure time intervals for events such as:

- a race between coins rolling across the floor
- the time it takes to turn 10 pages in a book
- the time it takes to sharpen a pencil

On the project page, set up a button to run the `reaction` procedure. In the button dialog box, select Type: On and then type `reaction` in the Action: On box.

Language Arts

Have the students place text blocks on the Project Page and add their names or write descriptive paragraphs about their activities. To set up a text block, click on the text tool (second from the top) on the left side of the Project Page, and then click anywhere in the Project Page. Drag one of the corners of the text box to the desired size. Click inside the text box and begin typing. To modify the font and other box characteristics, hold down the Shift key and double-click the text box. This will display the dialog box.

Social Studies

Have the students trace the history of measuring time and provide information about as many timekeeping devices as they can find.

Motion Exploration 4 The Dactamobile

Goal - Determine the speed of a simple motorized vehicle.

Specific Background Information

Knowing the speed of your automobile allows you to estimate travel time between destinations, to drive safely as road conditions change, and to insure compliance with local traffic laws. To find the speed of their Dactamobile, students must divide distance by time.

What To Do

Divide students into teams of two or three. Assign each team to a computer equipped with the Control System materials:

- Control Lab software - installed on hard disk
- Interface box, cable, and transformer - connected to computer
- Simple Control building set (item #9702)
- One angle sensor and one light sensor

Distribute Handout 4. (See copymaster on page 65.)

Handout Tips

In step 4 of the handout, students determine the scale factor for the Dactamobile as they did for the trundle in Exploration 2, Trundle On. If students are building models using the drawings, the scale factor will have the same value for the Dactamobile as for the trundle.

In step 5, students insert their scale factor in the blank in the `find.speed` procedure. The `find.speed` procedure calculates the average speed of the Dactamobile when it divides the distance traveled by the number of seconds. The `setpower` command controls the speed of the motor. Students can use numbers from 0 through 8 with `setpower`.

A procedure name must be a single word. In the procedure name `find.speed`, a period is used to combine two words into one.

In step 6, students decide the number of seconds they want the Dactamobile to run. For a 3-second run, they would type `find.speed 3` in the Command Center. (Make sure there is a space between `find.speed` and `3`.) The speed result of all runs should be about the same because the distance and the time of travel change in the same proportion. This means that the speed of the Dactamobile is not changing during the time it is running. The units of the speed depend on the scale factor. If the students use a scale factor based on centimeters, then the speed is in centimeters per second. Typical results are around 30 cm/s.

If the Dactamobile goes the wrong direction, students can either turn the connecting lead around on port A of the interface box or use the `rd` (reverse direction) command.

In step 7, students set up a photogate as they did in Exploration 3, Time Flies.

In step 8, students must divide the distance measured with a meter stick by the time it takes the Dactamobile to travel from the starting line to the photogate timer.

In step 9, the values are usually close but different. Help students focus on why the values might not be the same. For example, how carefully did they measure the distance from the start line to the photogate?

Building Tips

One key feature to emphasize is that of "gearing down." This means that a small gear or pulley wheel on the motor shaft should turn a larger gear or pulley wheel on the vehicle. Otherwise, the vehicle will travel too fast for introductory work. (Later, in the problem solving activities, students will have the opportunity to build a faster motorized vehicle.)

The model in the drawing has two different pairs of gears to help slow down the vehicle. The 8-tooth gear on the motor turns a 24-tooth crown gear, for a 1/3 speed reduction. Then an 8-tooth gear on the same axle as the crown gear turns a 24-tooth gear on the main axle, for a further 1/3 speed reduction, for an overall 1/9 speed reduction.

Suggest to students that they can produce longer connecting leads by clipping them together end to end. They will probably want to lengthen the angle sensor lead using this same technique. This will give their vehicles a little more freedom to move.

If students build the model in the drawings, the following tips might be helpful.

- Use the same frame as for the trundle.
- The beams beneath the motor are 12 studs long.
- Use a short beam with a black connector peg on the bottom of the angle sensor to secure it to the vehicle.

Students might enjoy exploring the average speed of non-motorized vehicle models rolling down a ramp. They measure the distance down the ramp and divide by the time it takes to roll to the bottom. Perhaps a photogate might be set up with the lamp and the light sensor at the finish line.

Programming Tips

The `find.speed` procedure is an example of a procedure that accepts a variable. It allows a student to operate the model for a certain number of seconds and then calculates the speed of the model during that time. The scale factor goes in the blank.

```
to find.speed :seconds ———————————————— :seconds holds a place for a variable number of seconds
resetrotation 7 ——————————————————————— resets the angle sensor in port7 to zero
talkto "motora ———————————————————————— prepares motor in port A for action
setpower 4 ———————————————————————————— reduces the speed of the motor*
onfor :seconds * 10 ——————————————————— turns on motor for a specified time
make "distance ___ * angle7 ——————————— calculates the distance**
make "speed :distance / :seconds —————— calculates the speed***
show sentence :speed [centimeters per second] —— displays calculated speed
end
```

*Even with gearing down, the Dactamobile may still be a bit fast. Using the `setpower` command slows the motor so that the vehicle speed might be "about right." Students can restore the motor to full speed with `setpower 8`.

**The `make` command assigns a value to a variable. In this case, the result of the calculation of the scale factor multiplied by the angle sensor reading is assigned to the variable named distance.

***The software uses a single set of quotation marks (`"`) to designate the *name* of an object or variable. In this case, `"speed` refers to the *name* of a variable called speed. The software uses a colon (:) to designate the *value* of a variable. Thus, `:speed` refers to the *value* calculated from `make "speed :distance / :seconds`.

The `find.time` procedure in step 7 of the handout is similar to the `reaction` procedure in Handout 3. It measures the time from the instant the model begins to move until it blocks the beam of light going into the light sensor.

```
to find.time
resett1 ——————————————————————— restarts timer #1 from zero
talkto "motora ———————————————— prepares the motor in port A for action
on ———————————————————————————— turns on the motor in port A
waituntil [light8 < 60] ——————— waits until the light beam is blocked
make "time timer1 / 10 ———————— calculates the travel time in seconds
show sentence :time [seconds] — displays the value of time and units
off ——————————————————————————— turns off the motor
end
```

Students can change the `find.speed` procedure so that it always reports positive values for speed regardless of which way their vehicle travels. To do so, they should change `angle7` to `(abs angle7)`, being sure to include the parentheses. This reports the positive (absolute) value of the angle sensor reading, even if it is actually negative.

Students may want to create a monitor on the Page1 project page to display the value of the speed from the `find.speed` procedure. In the monitor dialog box, they should select f(x) and type `:speed` in the function box. The value of the speed is displayed each time the `find.speed` procedure runs.

Interdisciplinary Extensions

Mathematics

In step 6 of the handout, students could use a meter stick to measure the distance their vehicles travel. Dividing this distance by the time would give a result to compare with the computer calculation.

Once students know the average speed of their Dactamobile, challenge them to *predict* how far their vehicle will go as a function of time. For example, they could use the `find.speed` procedure and predict how far their Dactamobile would go for `find.speed 4` or `find.speed 6.5`. Since distance equals vehicle speed multiplied by the time of travel, and the vehicle speed is fairly constant, then this challenge gives students the opportunity to explore direct proportions. The dependent variable (distance traveled) changes directly in proportion to the independent variable (time of travel). Thus, students should expect the Dactamobile to travel about twice as far for `find.speed 4` as for `find.speed 2`.

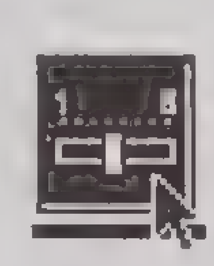
If students obtain negative numbers for average speeds with their `find.speed` procedures, it means that the vehicle is traveling in a direction that decreases the angle sensor values. Since the angle sensor count starts from zero, any decrease will result in a negative number. This might be a good time to discuss absolute value of numbers or to point out how the negative sign gives us information about the direction the vehicle travels.

Challenge students to create a procedure which calculates the average speed using information from the angle sensor *and* from a photogate timer. Such a procedure might be similar to the one following. The scale factor goes in the blank. The model could be placed at any distance from the photogate timer.

```
to move
resetrotation 7
talkto "motora
setpower 4
on
resett1
waituntil [light8 < 60]
make "time timer1
off
make "distance ___ * angle7
make "speed :distance / :time
show sentence :speed
  [centimeters per second]
end
```

Technology

Students can control the speed of their Dactamobile by use of a slider on the Project Page. To create a slider, click on the slider tool (the bottom tool) on the left side of the Project Page and then click in the Project Page.



Slider Tool

Hold down the Shift key and double-click the slider. In the dialog box, type the following in the "Release" box. Then click OK. This line of instructions sets the power of the motor in port A to the value of the slider (0 on the left through 8 on the right).

Release: `talkto "motora setpower slider1`

Remove the `setpower 4` command from the `find.speed` procedure so it will not interfere with the slider. To change the motor speed, move the slider to a new position and run the `find.speed` procedure. When the slider button is at the extreme right, it reports a value of 8; at the extreme left, a value of zero. (Students could also create a button to run the `find.speed` procedure. In the button dialog box they should select f(x) and type `find.speed 3` in the Action: On box.)

Perhaps students might enjoy a challenge with a steerable vehicle. Give students copies of the drawing below and let them determine the speed of a Dactamobile going in a circle!

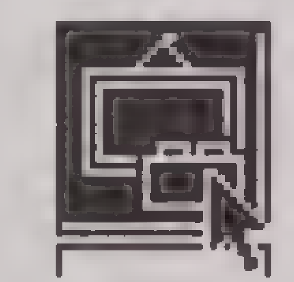
If two or more Simple Control building sets are available, ask student teams to set up two photogate timers to operate so that they can measure the average speed of a vehicle moving through both photogates. The light beam and sensor of the first photogate would start the timer and the light beam and sensor of the second photogate would stop the timer. Could a setup like this be used to determine the speed of vehicles on the highway?

Language Arts

Have the students write a one-act play in which the driver of a car is trying to talk his or her way out of a speeding ticket with a police officer by suggesting that the photogate method of obtaining the speed is not accurate.

Suggest that students "dress up" their Project Page with both text boxes and pictures. To create a picture on a Project Page, click on the picture tool (third from the top) on the left side of the page and then click in the Project Page. Hold down the Shift key and double-click the picture to display the dialog box. Click on the down arrow to select the desired shape for your picture. Then click OK.

Shape: Empty Pict.



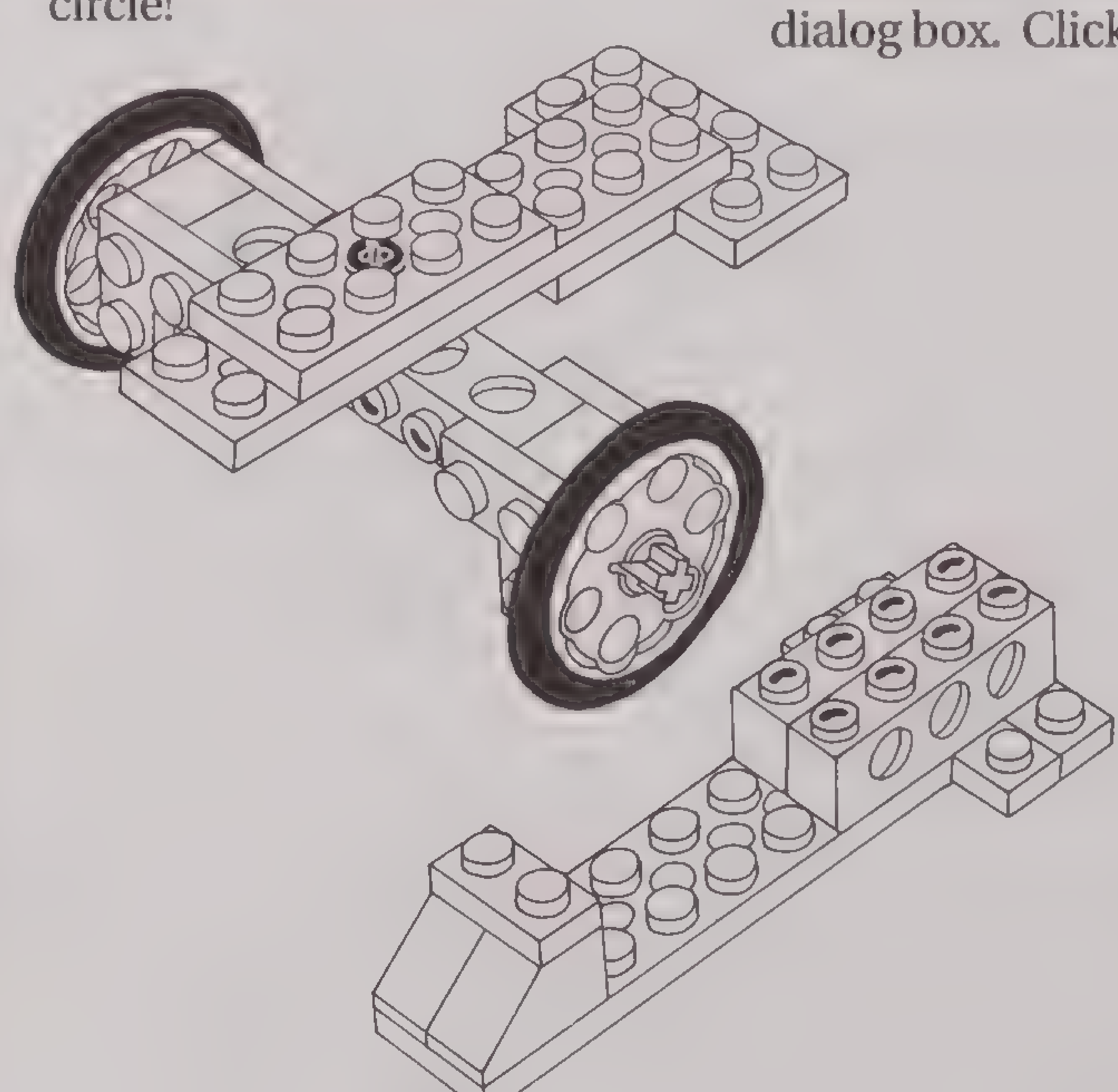
Picture Tool

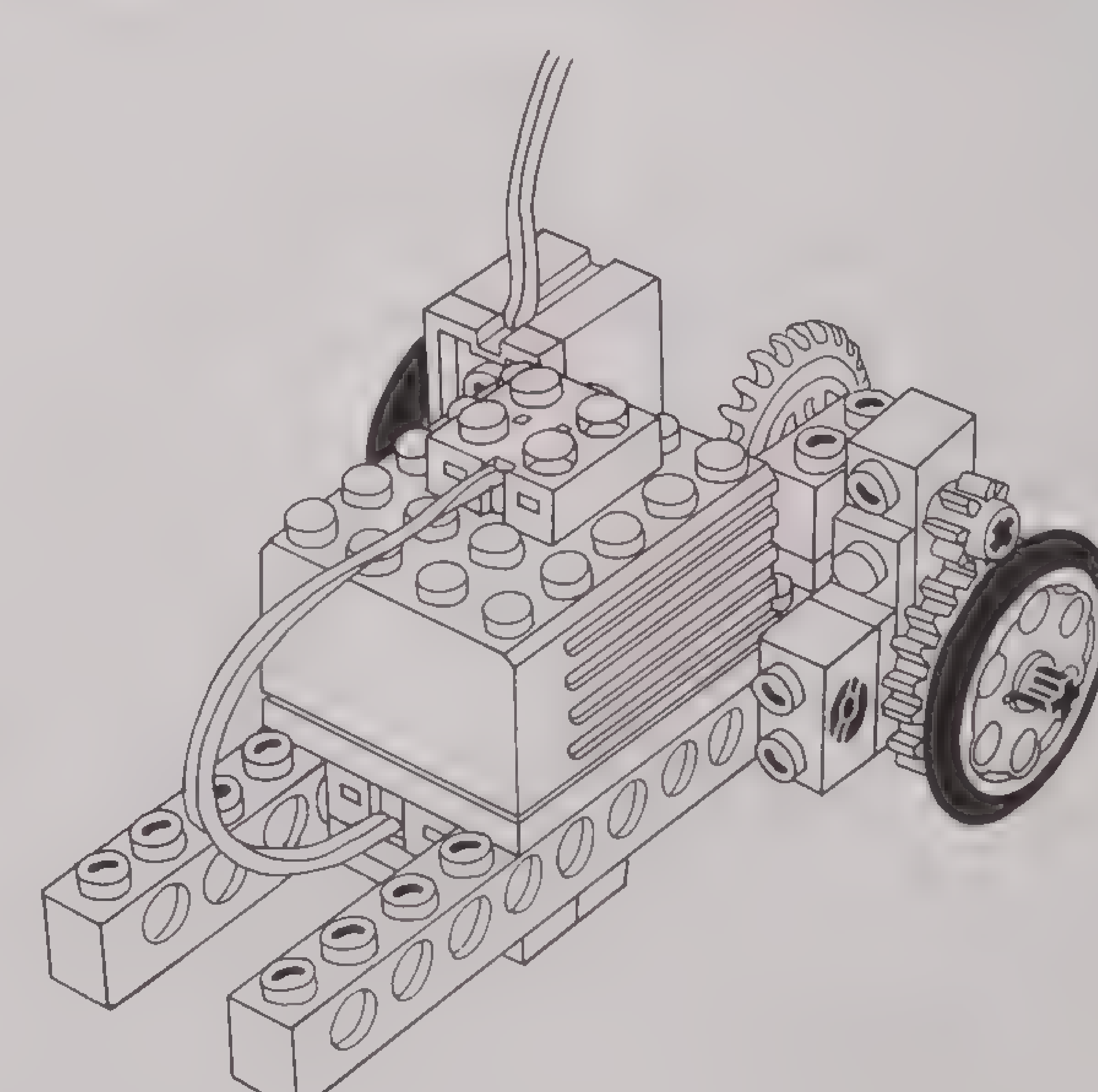
See pages 1.32- 1.34 of the *LEGO DACTA Control Lab Reference Guide* for more information on pictures.

Students can also create their own clip art in a picture box. See page 3.8 of the *LEGO DACTA Control Lab Reference Guide.*

Social Studies

Most jurisdictions use radar to detect the speed of a vehicle. Some jurisdictions connect the radar detector to a camera and take a picture of all vehicles traveling at a speed greater than the speed limit. These offenders then receive a speeding ticket through the mail along with a copy of the picture and the incriminating evidence. Encourage the students to discuss the legal and social aspects of such a practice.





Motion Investigation 1 Robotrike and Dactasaur

Goal - Measure the average speed of the Robotrike or the Dactasaur at different power settings using information from the angle sensor and from the light sensor.

Additional Materials Needed

- meter sticks
- stopwatches
- large pieces of white paper

What To Do

Divide the students into teams of two or three. Assign each team to a computer equipped with the Control System materials:

- Control Lab software - installed on hard drive
- Interface box, cable, and transformer - connected to computer
- Simple Control building set (item #9702)
- One angle sensor and one light sensor

Distribute Handout 5 to students. (See copymaster on page 68.)

Handout Tips

In step 1 of the handout, students use the building instructions from the Simple Control building set (item #9702).

In step 3, the Robotrike might go forward or turn to the right when students type `talkto "motora on`, depending on the orientation of the electrical connections. They can use the `rd` (reverse direction) command to change from one type of motion to the other. The Dactasaur walks either forward or backward, depending on the direction the motor is turning. The Dactasaur cannot turn left or right.

Note: Students find the Robotrike motion curious; encourage them to investigate it. The Robotrike travels straight ahead when the motor axle turns in one direction. When the direction of the motor spin is reversed, the Robotrike begins turning because the front wheel encounters the least resistance by swinging to the left. When the wheel reaches the limit of the swing, the rotational motion is transferred to the wheel axle, causing the vehicle to begin turning to the right.

In step 4, students must measure a distance and a time to find the average speed of their Robotrike or Dactasaur. They could use the `onfor` command to measure the time but encourage them to use stopwatches if available (to connect with their earlier reaction time activity). Typical values are around 15 cm/sec for the Robotrike and 3 cm/sec for the Dactasaur, depending on the surface.

In step 5, if students mount their angle sensor on their Dactasaur following the idea in the first drawing, their scale factor will be the same as for their trundle from Handout 2. If students use the idea in the second drawing for their Robotrike, then their scale factor will be three times as large as for the Handout 2 trundle wheel. The small 8-tooth gear on the side of the front Robotrike wheel turns three times as fast as the large 24-tooth gear (and the angle sensor). Thus, one turn of the axle angle sensor causes the front Robotrike wheel to turn three times. (Students may want to refer to Handout 2 to verify their scale factor.)

✏ **Teacher note:**

Students can change `angle7` to `(abs angle7)` in the `find.speed` procedure to eliminate negative values. Include the parentheses. This reports a positive (absolute) value from the angle sensor regardless of how the model moves.

In step 7, students can use the `find.speed` procedure from Handout 4 to determine the average speed of their models. If the Robotrike turns instead of going forward, students can use the `rd` (reverse direction) command before running the `find.speed` procedure. To run the model for three seconds, students type `find.speed 3` in the Command Center.

In step 8, students can use the `find.time` procedure from Handout 4 to obtain the time of travel from a starting line to the finish line at the photogate. Students place the model at the starting line and run their procedure.

In step 9, the values will probably be fairly close together. Students might suggest reaction time, distance measuring accuracy, and other factors to account for any differences.

Building Tips

Robotrike

In step 8 of the building instructions, be sure to put the rubber band over the pulley wheels before attaching the red beams. The worm gear (it looks like a threaded screw) helps make the model move slowly. One complete rotation of the worm gear moves the 40-tooth gear by one tooth. Thus, it takes 40 turns of the worm gear to turn the 40-tooth gear one time.

Since the Robotrike turns only to the right, the connecting leads may become twisted after several turns. If this happens, students can disconnect the leads, untwist them, and reattach them.

Dactasaur

In step 5 of the building instructions, students could connect the tail to the body with gray connector pegs instead of black ones to produce more consistent angle sensor readings.

In step 6 of the building instructions, note that six-stud beams are attached vertically on each side of the motor.

In steps 8 and 9 of the building instructions, pay particular attention to how the legs are attached.

Interdisciplinary Extensions

Mathematics

Can be Robotrike or the Dactasaur measure distance accurately? Challenge students to support their response with experimental data.

After an average speed has been determined, have the students predict the distance the Robotrike or Dactasaur will travel in a certain amount of time. Have them measure the actual distance traveled during that time interval and compare that measurement to the prediction using percent difference.

Use the `setpower` command and repeat the above investigation with different speeds.

Have one student graph the movement of the team model without the other team members watching. Then challenge the team members to describe the model movement using only information on the graph. For example, "Here it moved forward, then it stopped for a few seconds. Then it started moving forward again, but a lot slower."

Place the TECHNIC pen in the position on the Robotrike suggested by building card 9702-3, step 10. Have the students program the Robotrike to draw various geometric figures, such as triangles and squares, on a large piece of paper on the floor.

Technology

Build an obstacle course for students to negotiate with their Robotrikes. Allow them to use procedures, buttons, sliders, or any other computer techniques to control their models. Perhaps use a photogate timer to measure total elapsed time as well as help measure average speed.

Ask students to mount the light sensor on their models and use the lamp and parabolic reflector to control them. If they type in the Command Center

```
forever [talkto "motora
if light8 > 90 [onfor 1]]
```

all on one line, their model will spring into action whenever they shine the light into the sensor. They can use the `stopall` command to stop the `forever` process.

Language Arts

Write a paragraph explaining the unique movement of the Robotrike or the Dactasaurus in detail so that a person who has never seen the model will understand how it has to be controlled.

Suggest to students that they build the model of a rotating stage with building instruction 9702-1 and write a play to produce on such a stage.

Social Studies

The picture on the front of building card 9702-3 shows a vehicle used to paint lines on roads and highways. Why do we have such lines? What would happen if we had no such vehicles to paint these lines?

Select a particular dinosaur and build a LEGO® model of it. Write a brief report about the dinosaur, including vital statistics, diet, and habitat. What lessons can we learn about life long ago?

Motion
Invention 1
Zipping Along

Goal - Invent and build a motorized vehicle with a high average speed.

Additional Materials Needed

- meter sticks
- stopwatches
- calculators
- markers

Specific Background Information

Fast moving vehicles are all around us. The Indianapolis 500 is a classic example of the popularity of fast cars. Some public vehicles are designed for high speed as well, such as ambulances and other emergency vehicles.

Distance divided by time is still valid for determining the speed of fast moving vehicles. The main problem becomes figuring out when the fast moving vehicle goes past a point to stop the timer. Fortunately, with computer sensors this task can be automated.

What To Do

A day or two ahead of time, ask students to start thinking about how they might invent a fast-moving model vehicle made from LEGO® elements. Encourage students to develop preliminary sketches and to share ideas with each other.

Divide the students into teams of two or three. Assign each team to a computer equipped with the Control System materials:

- Control Lab software - installed on hard disk
- Interface box, cable, and transformer - connected to computer
- Simple Control building set (item #9702)
- One angle sensor and one light sensor

Challenge student teams to invent and build a fast motorized vehicle. They must determine the average speed of their vehicle without sensors and then with the use of either an angle sensor or a light sensor, or both.

Designate a raceway area for students to use in testing their vehicles. Each team can demonstrate the average speed of their vehicle after delivering a brief report. Speeds in excess of 100 centimeters per second are possible.

Building Tips

A vehicle with a wide wheel base would be most stable at high speeds. Students could also experiment with other ways to keep their vehicles on course, such as string guides and guide rails.

The building cards in the Simple Control set contain several proven techniques, including using a rubber band for the power connection to the motor.

Because the vehicle covers a large distance in a small amount of time, students might not choose to incorporate the angle sensor into the vehicle design. The photogate timer is a common choice to determine the speed of fast vehicles.

Students can clip several connecting leads end to end to make one long lead. This will provide power to the vehicle over a longer distance.

Programming Tips

Encourage students to use procedures they developed in earlier activities. For example, the `find.time` procedure would work well here with a photogate timer.

Data Processing Tips

Because students will be measuring over relatively short periods of time, they should calculate their speed based on several time trials.

Assessment Ideas

Here are some questions students might use in evaluating their vehicles.

How fast did the vehicle go?

Is the vehicle stable at high speeds?

How consistent was the speed measurement?

How well does the vehicle hold up to repeated time trials?

How much cargo can the vehicle carry?

Interdisciplinary Extensions

Mathematics

Ask students to have their vehicles travel at a slower speed during the first few seconds of their time trials and then travel at a faster speed until they reach the finish line. Below is a variation of the `find.time` procedure from Handout 4 which might be used with a photogate to find the time of travel. Note that `setpower 3 onfor 20` makes the vehicle go slowly for two seconds. Then `setpower 8 on` lets the vehicle travel at maximum speed until it breaks the light beam. To calculate the overall average speed, students divide the total distance by the time reported from the `slow.fast.time` procedure.

```
to slow.fast.time
resett1
talkto "motora
setpower 3
onfor 20
setpower 8
on
waituntil [light8 < 60]
make "time timer1 / 10
show sentence :time
  [seconds]
off
end
```

Technology

Speed is often related to production output. Describe how manufacturing operations might be enhanced by speedy delivery vehicles.

Ask students to add a cargo bay to their vehicles. Compare the average speed with and without a heavy load.

Sometimes a wheeled vehicle cannot travel over extremely bumpy or wet terrain. Wheels are useless. Challenge students to invent a motorized walking vehicle and determine its average speed. They may want to study the walking mechanism in building card 9702-4 as a point of departure.

Language Arts

Einstein and other scientists have suggested that time slows down as the vehicle in which we are traveling goes faster and faster. This idea has been popularized in recent films such as *Back to the Future.* Ask students to write a fictional account of a trip in an ultra-fast time travel vehicle.

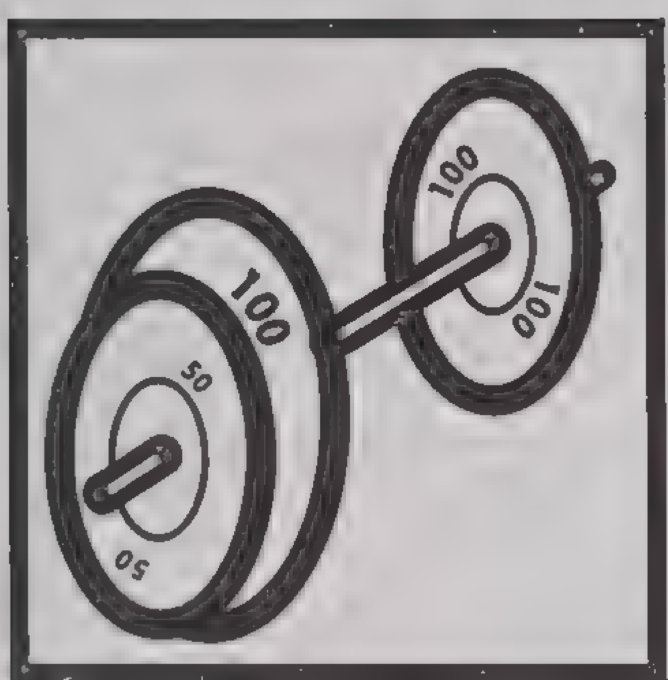
Challenge students to redesign their vehicles to resemble time traveling machines. Add compartments to provide any necessary items for time travelers.

Social Studies

Speed control of vehicles is a serious concern of government, not only to protect people from injury but also to conserve fossil fuels. Discuss why citizens might not want the government to set speed limits for their personal vehicles, even though they are safer traveling at slower speeds, fossil fuels would be conserved, and the environment would be less polluted.

Unit II

It's a Workout: Work, Power, and Energy as a Study of Change



Objectives

The purpose of this unit is to introduce the students to the concepts of work, power, and energy through the Control System activities and the Control Lab software and interface box. At the end of this unit, each student will be able to:

- Define and measure work as a change in potential energy using
  - ordinary tools (meter sticks and scales)
  - computer-based tools(information from an angle sensor)
- Define and calculate power
- Define and measure force as it relates to work
- Use the computer appropriately for detecting changes in distance and time and, with this information, determine work and power

Activity Listing

	Exploration 1	Explore work done by a winch
	Investigation 1	Determine work done by an elevator
	Invention 1	Build a device which can lift heavy loads

Note: Several activities in this unit require students to write procedures (small computer programs). If your students do not know how to write procedures, refer to Exploration 1 of Unit I on page 13. You might also photocopy the procedure section from the *Control System Quick Reference Guide* for your students.

Additional Materials Needed

- meter sticks
- stopwatches
- laboratory mass sets and small objects to be lifted
- spring scales

Background Information

The inventing, combining, and powering of machines have always been directed toward one goal: reducing the human effort, cost, and time needed to do work. As we approach the 21st century, there is still plenty of work to be done. More than ever, we still need machines and energy to do the work as easily and as quickly as possible.

Energy

Energy is the name we give to the capability of doing work. Energy can take many forms. In this unit, we deal mainly with energy of position (potential energy). We will also refer to energy of motion (kinetic energy).

The Law of Conservation of Energy states that energy can be neither created nor destroyed. The total amount of energy in the universe always remains the same. In this unit, we apply this law to much smaller energy systems.

Work

Work is done when a force (a push or a pull) moves an object some distance. Work requires energy. The mathematical formula for work is

$$\boxed{\textbf{Work} = \textbf{Force} \times \textbf{Distance}}$$

Typical units for work are

Work = Force (newtons) x Distance (meters)
= newton-meters (or joules)
Work = Force (pounds) x Distance (feet)
= foot-pounds

One newton is equal to about 1/4 pound in customary units.

If either the applied force or the distance moved is zero, then no work is done. For example, if you push on a wall with a force of 445 newtons (100 pounds) and the wall does not move, you are not doing any work, regardless of how tired you might feel!

The Simple Control building set (item #9702) weighs about 8 newtons (about 2 pounds). If you lift the set to a height of 2 meters (about 6 feet), you must apply an upward force of about 8 newtons (about 2 pounds). In doing so, you are performing work as follows.

Work = 8 newtons x 2 meters
= 16 newton-meters (or joules)
Work = 2 pounds x 6 feet
= 12 foot-pounds

As you lift the set, you are giving it potential energy. This energy could be converted to kinetic energy by allowing the set to fall. The falling set could do work by pushing against another object.

Power

Power is an indication of how fast work is done. A powerful engine can do a lot of work in a short amount of time. This also means that it requires a lot of energy in that time.

The mathematical formula for power is

$$\textbf{Power} = \frac{\textbf{Work}}{\textbf{Time}}$$

Typical units for power are

Power = Work (newton-meters) / Time (seconds)
= newton-meters per second (or watts)
= joules per second (or watts)

Power = Work (foot-pounds) / Time (seconds)
= foot-pounds per second

If it took 4 seconds to lift the Simple Control set up 2 meters or 6 feet, the power needed would be

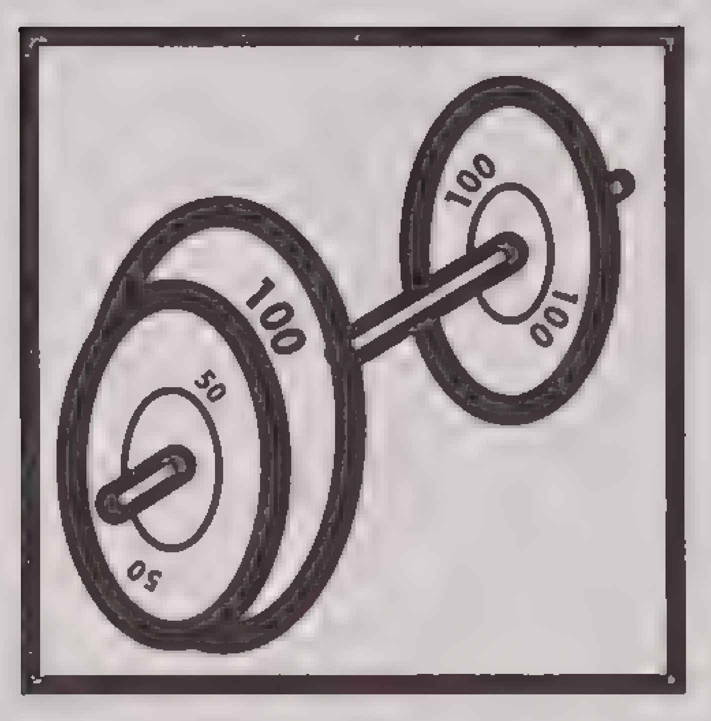
Power = 16 newton-meters / 4 seconds
= 4 newton-meters per second (watts)

Power = 12 foot-pounds / 4 seconds
= 3 foot-pounds per second

Power is also expressed in the customary unit of horsepower. Originally, the term was used to compare the work output of a typical draft horse to other power sources, such as a steam engine. One horsepower equals 550 foot-pounds per second or 746 newton-meters per second. The results in the example above equate to about 0.005 horsepower (4 / 746 = 0.005 and 3 / 550 = 0.005).

Hints and Tips

Students will find that geared down models of winches with slowly rotating axles can lift heavy loads. Gearing down means that a small gear turns a larger gear. For example, students could use an 8-tooth gear to turn a 24-tooth gear, creating a 3 to 1 mechanical advantage (24 divided by 8 equals 3). This means that the small gear must turn 3 times in order to turn the larger gear once. But it also means that the force needed to turn the small gear is less.



Work, Power, and Energy Exploration 1
Crank It Up

Goal - Determine how much work, power, and change in potential energy can be produced with a hand-operated winch.

Additional Materials Needed

- stopwatches
- meter sticks
- several small objects to be lifted by the winch
- spring scale for measuring weight

What To Do

Introduce the students to the scientific concept of work (force times distance). Challenge them with one or more of the following activities and then ask them how much work they performed. Surprise! The answer is zero, at least in the scientific sense. In order for work to be performed, a force has to move an object through a distance. In these activities nothing moves, so no work is done.

- Hold a book at arm's length for a while
- Push steadily against the wall as forcefully as possible
- Perform an isometric exercise (e.g., clasp hands in front of chest and pull) for several seconds

Let students explore their own energy and power. Students time each other as they walk quickly up a flight of stairs. They multiply their weight (force in newtons or pounds) by the total height of the stairs (distance in meters or feet) to get the work they perform in climbing the stairs. This is also the change in their potential energy. (Multiply pounds by 4.45 to convert to newtons if you are using metric units.) They divide the work by the time in seconds to get their power (in newton-meters per second or foot-pounds per second). Then divide metric unit work by 746 or customary unit work by 550 to obtain the horsepower. How does this compare with a horse (one horsepower)? How many students must combine their efforts to equate to one horsepower?

Divide students into teams of two or three. Assign each team to a computer equipped with the Control System materials:

- Control Lab software - installed on hard drive
- Interface box, cable, and transformer - connected to computer
- Simple Control building set (item #9702)
- One angle sensor

Distribute Handout 6 to student teams. (See copymaster on page 71.)

Handout Tips

In step 1 of the handout, the winch shown is based on a gearing down mechanism, in which a small gear turns a larger gear. The string is wound up on the axle with the larger gear.

In step 2, if students wish to use customary units instead of metric units, they could measure in pounds and feet, and then make the appropriate substitutions. For example, in step 2 they would record pounds, and in step 4 they would record feet. For best results, objects should weigh at least 4 newtons or 1 pound.

In step 4, if students select a distance of less than one meter, they should record the distance in decimal form. For example, if they are raising an object 40 centimeters, they should record a distance of 0.40 meters.

In step 5, one student operates the stopwatch or timer while another turns the winch handle. A third student (if present) could give the start and stop signals and verify the distance.

In step 6, students must multiply the weight of the object by the distance they raised it to calculate the work. They divide the work by the time to find the power. If students are using customary units, the work would be in foot-pounds and the power in foot-pounds / second. Make sure students realize that they are increasing the potential energy (energy of position) of the object when they perform work on it by raising it up. They could change this potential energy to kinetic energy (energy of motion) by releasing the object and letting it fall!

In step 7, the drawing shows one example of several ways to attach the angle sensor.

In step 8, students might want to add to or use an earlier project file. They could do this by going to the File menu and selecting Open Project. They can add additional project pages by going to the Pages menu and selecting New Page.

In step 9, you may wish to refer to Motion Exploration 2, Trundle On, if your students have not yet learned how to set up a button and a monitor.

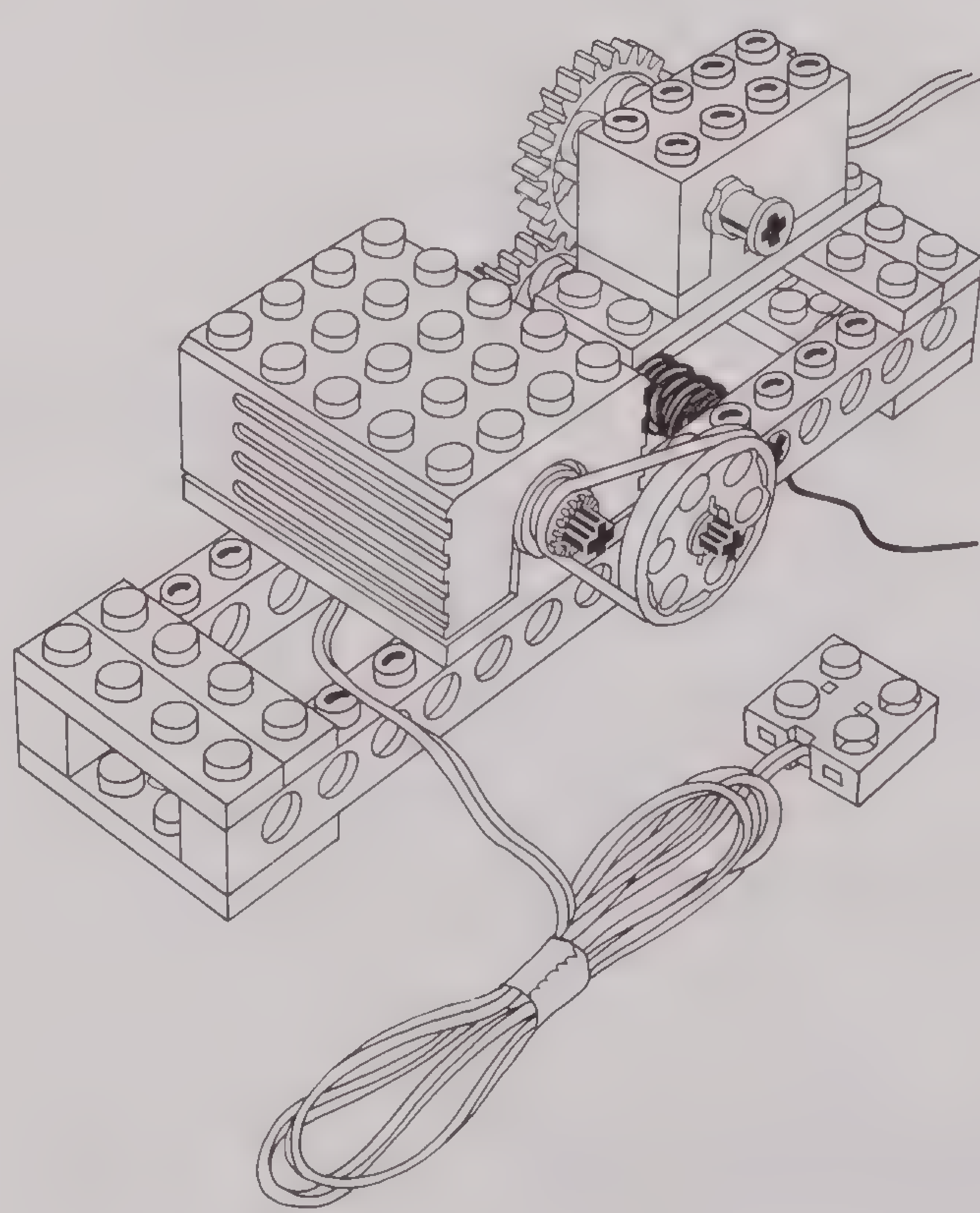
In step 11, the `lift` procedure was written assuming that students are weighing their objects in newtons and raising them up a height of 0.20 meters (20 centimeters). If they are weighing their objects in pounds and raising them a distance in feet, then they put the weight in pounds in the second blank in the `lift` procedure and substitute the height in feet for 0.20. They should also use the following three lines in their procedure instead of those in the handout.

```
show sentence :work [foot-pounds]
show sentence :power [foot-pounds per second]
show sentence :power / 550 [horsepower]
```

In step 12, students do not have to begin turning the winch handle the instant they press Return or Enter; the `lift` procedure waits until they begin cranking before it resets and starts the timer.

In step 13, students discover that the amount of work they performed in both cases is about the same; that is, they raised the same object up the same distance. However, there are often variations in the value for the power because students may take more time to raise the object during one attempt than in another.

Ask students to repeat the activity after adding a motor to their winch and compare their results with those from the hand-operated winch. The drawing below might be helpful.



You may wish to provide your students with the `raise` procedure listed below for use with their motorized winches. It is similar to the `lift` procedure. Note the use of `abs` in the `waituntil` line to insure that a positive value (absolute value) from the angle sensor is always reported regardless of which way the string is wound up.

```
to raise
resetrotation 7
resett1
talkto "motora
on
waituntil [(abs angle7) > ____]
off
make "time timer1 / 10
make "work ___ * 0.20
make "power :work / :time
show sentence :work [newton-meters]
show sentence :power [newton-meters per second]
show sentence :power / 746 [horsepower]
end
```

Students might discover that their motorized winch can lift some surprisingly heavy objects. They also discover that the objects travel downward much faster than they travel upward! If necessary, remind them that the `rd` command can be used to change the direction of the motor.

Programming Tips

The `lift` procedure in step 11 of the handout is an example of a procedure that calculates several values based on sensor and timer information. It assumes an object whose weight is measured in newtons is being raised a height of 20 centimeters (0.20 meters). Talk students through the procedure so they understand what it does.

Note the use of `(abs angle7)` in the `lift` procedure. This reports a positive (absolute) value from the angle sensor regardless of which direction the axle turns to wind up the string.

```
to lift
resetrotation 7 ——————————— resets the angle sensor in port 7 to zero
waituntil [(abs angle7) > 0] ——————— signals when cranking begins
resett1 ——————————————— restarts timer #1 from zero
waituntil [(abs angle7) > ___] ——————— signals when height is reached*
make "time timer1 / 10 ——————————— assigns number of seconds to time
make "work ___ * 0.20 ——————————— calculates work (force times distance)**
make "power :work / :time ——————————— calculates power***
show sentence :work [newton-meters] ——————— displays work
show sentence :power [newton-meters per second] —— displays power
show sentence :power / 746 [horsepower] ————— displays horsepower
end
```

* The 20-centimeter angle sensor reading from step 10 goes in the first blank.

** The weight of the object in newtons goes in the second blank.

***The Control Lab software uses a single set of quotation marks (") to designate the *name* of an object or variable. Here, `"power` refers to the *name* of a variable called power. The software uses a colon (:) to designate the *value* of a variable. Thus, `:power` refers to the *value* calculated from `make "power :work / :time`.

Students may wish to operate the motor and the sound element at the same time. The following instruction line might be helpful.

```
talkto [motora soundc]
```

Students can print their procedures by going to the Procedures Page and then typing `printtext` in the Command Center.

Building Tips

The most powerful winches will use a gearing down mechanism, in which a small gear turns a larger one. The winch in the drawing shows an 8-tooth gear turning a 24-tooth gear.

If the string becomes tangled in the gears of the motorized winch, students can remove the rubber band from the motor to free the axles to rotate so that the string can be pulled out easily.

Interdisciplinary Extensions

Mathematics

Since work is the product of an applied force multiplied by the distance the force moves an object (W = F x D), work is always zero if either the force or the distance is zero. Zero distance means the object does not move. Discuss with the class how zero work can be done, even in the presence of an extremely large applied force. Unless the object moves some distance, no work is done.

Select a convenient value for a quantity of work, such as 24 newton-meters. Ask students to suggest pairs of force and distance quantities which produce this amount of work. One example is a force of 4 newtons moving an object through 6 meters. Students can use calculators to discover other pairs. Make a table of the pairs of values and have students graph them with force along one axis and distance along the other. The result is a curve called a hyperbola.

Tell students about the stair climbing races up a portion of the CN Tower™ in Toronto, billed as the world's tallest free-standing structure at 553 meters (1815 ft). Brendan Keenoy holds the male record, climbing 1760 seven-inch steps up a 313-meter (1,027 ft) height in 7 minutes and 52 seconds. Debbie Jensen broke her own record for the female title in 1993 with a time of 11 minutes and 36 seconds. Ask students to make assumptions about their weight and estimate the power rating of Brendan and Debbie. (Answers: Assuming 675 newtons (150 pounds) for Brendan, he performed 211,275 newton-meters of work (154,050 foot-pounds), for a power rating of 447.6 newton-meters per second (326.4 foot-pounds per second), or about 0.6 horsepower. Assuming 540 newtons (120 pounds) for Debbie, she performed 169,020 newton-meters (123,240 foot-pounds) of work, for a power rating of 242.8 newton-meters per second (177 foot-pounds per second), or about 0.3 horsepower.)

Students can display their work, power, and horsepower values in monitors on Page1 when running the `lift` procedure. To set up a monitor to show the calculated work, for example, they select `f(x)` from the Show box in the monitor dialog box, type in `:work` (note the colon), and click OK. The value in the monitor is updated each time the `lift` procedure is run.

Challenge students to graph the value of the angle sensor as they raise and lower objects. Have them print out the graphs and ask other students to interpret them.

Have the class prepare a data table with the work, power, and horsepower results from all student teams. Ask the students to calculate the class average values for work, power, and horsepower and discuss any team results which are more distant from the averages. (The most likely reason for differences will be loads of different weights, winches with different gearing down arrangements, and motors being operated at different speeds. Other factors include inconsistent distance measurements, reaction time for stopwatches, and inaccurate measurements of weight.)

Technology

Discuss with students typical machines in transportation, construction, and manufacturing settings which make work easier to perform. Examples include fork lifts, cranes, and robot arms.

Challenge students to develop a procedure for lowering the object back to the starting level with their motorized winch. The `lower` procedure below is one possibility. Students will probably have to adjust the value after the < sign to allow for the proper amount of overrun so that the object comes to rest with the angle sensor reading zero.

```
to lower
talkto "motora
setleft
on
waituntil [(abs angle7) < 4]
off
end
```

Challenge students to use a photogate timer to measure the time it takes to raise an object. (See Motion Exploration 3, Time Flies.) Compare the power results with those obtained using stopwatches.

Discuss with students how winches might be used at construction sites.

Language Arts

Write a fictional story about a climb to the top of something very tall, such as a mountain or building. Include reference to the amount of work done.

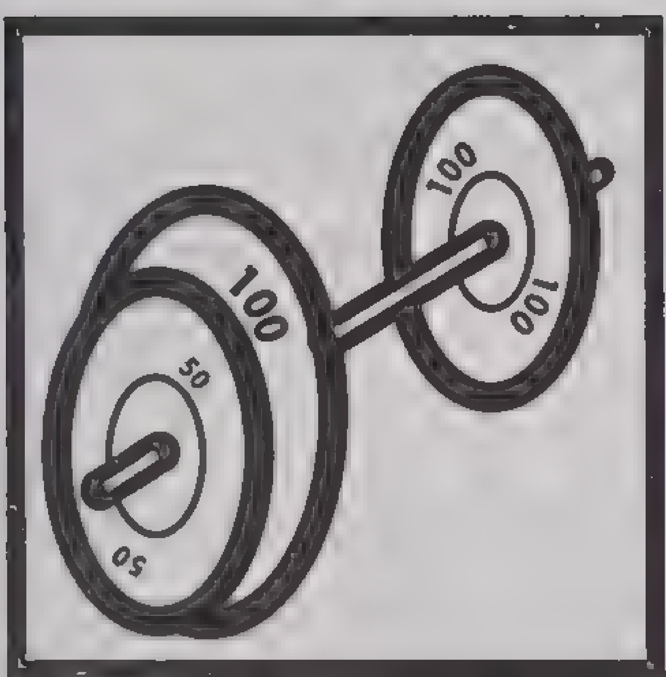
Suggest that students add text boxes to Page1 to explain the activity to someone who is new to the class. They could also print out the page with text boxes for a bulletin board display.

Social Studies

Identify some jobs which require a lot of physical work. Do you believe most people are paid for the amount of physical work they accomplish? Name some jobs that require little or no physical work, yet are high paying. (Corporate executives.) Name some jobs that are lowing paying that require a great deal of physical work. (Laborers.) Name some job that are high paying that require tremendous amounts of physical work. (Professional athletes.)

Ask the students to develop a time line showing the development of a selected tool or machine. Centuries ago, the tool was probably operated by hand. As animals were domesticated, maybe a horse was harnessed to provide the force. In the Middle Ages, perhaps it was powered by water. A century ago, maybe a steam engine was connected. A few years later, an electric or gasoline motor might have provided the power. Today, perhaps the same machine is solar powered and controlled by a computer.

What is the importance of motorized machines to society of today? Some older folks long for the “good old days.” Have the students describe what they think the “good old days” (i.e., the 1890’s, the 1920’s, the 1950’s) were really like. Would any of them actually want to live in those times? Have them explain their reasons for and against bringing back those “good old days.”



Work, Power, and Energy Investigation 1
Hi Ho Horsepower

Goal - Measure work, power, horsepower, and change in potential energy of a model motorized elevator.

Additional Materials Needed

- meter sticks
- spring scales to measure weight
- stopwatches

What To Do

Divide the students into teams of two or three. Assign each team to a computer equipped with the Control System materials:

- Control Lab software - installed on hard disk
- Interface box, cable, and transformer - connected to computer
- Simple Control building set (item #9702)
- One angle sensor

Distribute Handout 7 to students. (See copymaster on page 74.)

Handout Tips

In step 1 of the handout, students use building card 9702-2 from the Simple Control building set. They must stop in building step 8 because they need to weigh the cage before installing it in the elevator.

In step 2, students weigh the cage in newtons (about 0.5 newtons). If students are working in customary units, they should convert the weight of the cage in ounces (about 1.8 ounces) to pounds (1.8 / 16 = 0.11 pounds) since work is measured in foot-pounds.

In step 7, a common error is for students to measure from the bottom of the cage to the top of the shaft (20 or 21 centimeters). The elevator does not travel this distance. They need to focus on the change in position of the elevator. For example, they should measure from the bottom of the elevator when it is at the bottom of the shaft to the bottom of the elevator when it is at the top of the shaft (about 13 centimeters, recorded in the handout as 0.13 meters). If students measured the weight of the cage in pounds in step 2 above, they should measure the distance in step 7 in feet. They will have to convert their distance (about 5 inches) to a decimal fraction (5/12 = 0.42 feet) since the distance is less than one foot.

In step 8, students multiply the force (weight of the cage) times the distance (height elevator goes up) to find the work (about 0.65 newton-meters or about 0.46 foot-pounds).

In step 9, the elevator takes about 3 seconds to travel up to the top. Students can type commands such as `onfor 30` in the Command Center to check the time. However, for this part of the exercise you might want them to use stopwatches.

In step 10, typical values are 0.22 newton-meters / second or 0.15 foot-pounds / second. These values convert to about 0.0003 horsepower!

In step 13, a typical value is around 100.

In step 14, students need to determine if `setright` or `setleft` sets the proper direction of the motor to raise the elevator. One way to do this is to go to the Setup Page and click momentarily on the buttons above the motor icon on port A. If clicking on the rightmost button starts to raise the elevator, then `setright` is the command to use in the `goingup` procedure; otherwise, the `setleft` command should be used.

In step 15, the amount of work will be about the same. The power values may be different, depending on how the time was measured in step 9.

Building Tips

Be sure to point out to students the gearing down arrangement of the pulley wheels and gears in the elevator model. This enables the motor to lift fairly heavy loads; however, what it gains in lifting force it loses in speed.

In the elevator model, there are three pairs of pulley wheels or gears connected to the motor. In each case, a small wheel is turning a larger one.

1. A small pulley wheel on the motor turns a larger pulley wheel with a belt drive.
2. On the same axle as the large pulley wheel is a small pulley wheel that turns a large pulley wheel on another axle.
3. The second large pulley wheel also turns a small 8-tooth gear that turns a larger 24-tooth gear to wind up the string.

For each of the two pairs of pulley wheels in this model, it takes about three turns of the small pulley wheel to turn the large pulley wheel once. For the gears, it takes exactly three turns of the 8-tooth gear to turn the 24-tooth gear once. This means that the motor has to turn 27 times (3 x 3 x 3) to turn the 24-tooth gear once. This is why the motor runs fast but the winch winds slowly.

After the students complete step 6 on the building card, you might suggest that they turn the motor shaft by hand and observe how slowly the pulley wheels and gears turn in response.

Interdisciplinary Extensions

Mathematics

Set up a graph on a project page to graph the angle sensor reading as the elevator goes up and down. Identify the points on the graph where the elevator reached the top and the bottom of the elevator shaft. You might want to set up buttons and a monitor on the project page.

Determine the speed of the elevator going up and going down for various motor speeds. (Use the `setpower` command to change the speed of the motor.) Repeat your investigation with a 100 gram mass in the elevator cage as a load.

Place a lamp on the elevator and a light sensor on the base beneath it. Turn on the light. Graph the changing values of the light sensor as the elevator goes up and down. Discuss the meaning of the changing values.

Technology

Modern day elevators have several systems to prevent the cage from plunging to the bottom if a cable breaks. Have the students design and build a modification to their elevator models to prevent such a crash.

Set up an elevator control panel on a project page. Include buttons to move the elevator up and down and a slider to change the elevator speed. What else would you add so that you could stop the elevator at the top and at the bottom without seeing the elevator?

Set up a monitor on a project page to show the distance the elevator has been raised or lowered using input from the angle sensor. If the angle sensor reads 0 at the bottom and around 100 at the top, the following line could be typed into the f(x) box in the monitor dialog box to display the distance from the bottom in centimeters.

```
0.13 * angle7
```

Students used the weight of the cage to determine work and power in their model elevator. Why do they not need the weight of the elevator cage to determine the work performed by an actual elevator? (Because most modern elevators have a counterweight connected to the elevator cage by a strong cable going up over a pulley wheel. As the elevator goes up, the counterweight goes down. Since the counterweight approximately balances the weight of the elevator cage, the elevator motor has to lift only the weight of the passengers.)

Language Arts

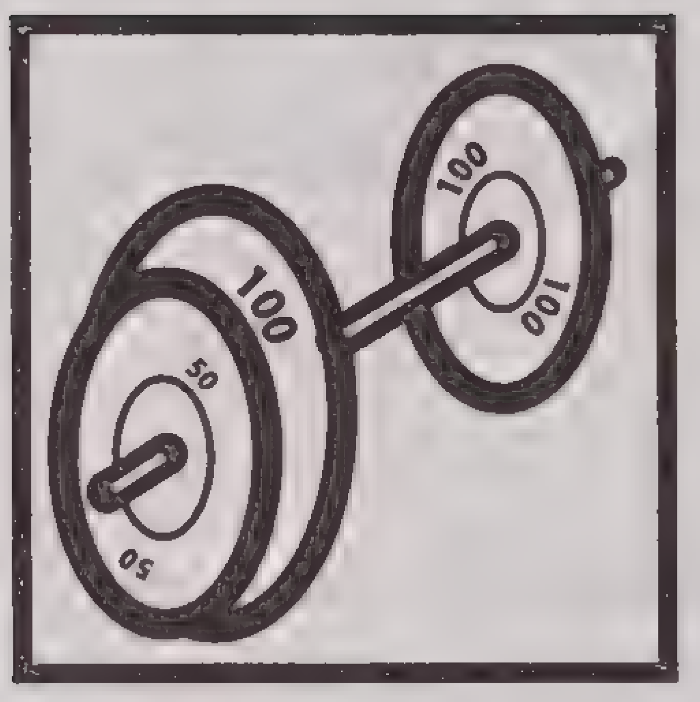
Horsepower is a term that appears in everyday language, despite the fact that it has a strictly scientific definition: 1 hp = 746 watts = 746 newton-meters of work being accomplished in one second. Are there other scientific terms terms which also are used informally in everyday conversation? (Suggestions might include force, work, and energy.)

Ask students to add text and graphic boxes to their project pages. Print out their project pages and display them on the bulletin board.

Social Studies

Have the students trace the history of the term *horsepower.* Who coined the term? What particular horse was used to set the standard? When was the term first used? Why was the term invented? Is this a unit that has no use today?

Try to imagine what large cities would look like today if the elevator had not been invented. Buildings could be only as tall as normal people could climb several times a day. Cities would cover much more area because they would have to build out instead of up. Write a brief description of how this would affect everyday life in the city.



Work, Power, and Energy Invention 1 Uplifting Experience

Goal - Invent, build, and program a device that can lift the heaviest load possible.

Additional Materials Needed

- laboratory mass sets and various other objects to be raised
- spring scale for weighing masses and objects

What To Do

A day or two ahead of time, ask students to start thinking about how they might invent, build, and program a device that can lift the heaviest load possible. Encourage students to develop preliminary sketches and to share ideas with each other.

Divide the students into teams of two or three. Assign each team to a computer equipped with the Control System materials:

- Control Lab software - installed on hard disk
- Interface box, cable, and transformer - connected to computer
- Simple Control building set (item #9702)
- One angle sensor and one light sensor

Challenge student teams to invent, build and program a device that can lift the heaviest load possible. They must determine the amount of work done by their device and its power output. The angle sensor and light sensor can be used to determine time and distance, if desired.

Assist students as appropriate.

Building Tips

For lifting heavy loads, students could use a gearing down arrangement similar to that used in the earlier exercises. They could borrow ideas from models built previously.

To lift the heaviest load possible, they will probably need several pairs of pulley wheels and gears connected together as they did in building the elevator model.

Programming Tips

Encourage students to use procedures they developed in earlier activities.

Assessment Ideas

Here are some questions students might use in evaluating their devices.

What was the heaviest load the device could lift?

How much work did the device do in lifting the load?

How much time did the device need to lift the load?

How much power was required to lift the load?

How well does the device perform over repeated lifts?

Interdisciplinary Extensions

Mathematics

The future of modern civilization may be tied to controlling nuclear fusion and the equation $E = mc^2$. During nuclear fusion, a small amount of matter is changed directly into energy. How much energy would be generated by converting just one milligram (i.e., 0.001 gram or one thousandth of a gram) of matter into energy? (Answer: $E = mc^2 = (.000001\ \text{kg})\ (300{,}000{,}000\ \text{m/sec})^2 =$ 90,000,000,000 joules of energy; this is enough energy to lift 30,000 fully loaded gravel trucks (at 33 tons each) a distance of 10 meters (30+ feet) off the surface of the earth at the same time)

Technology

Plans for many perpetual motions machines have been patented. However, this does not mean that they actually function as their inventors hope. What law of nature does a perpetual motion machine violate? (It violates the Law of Conservation of Energy.)

In practical terms, why are perpetual motion machines impossible to build? (The system would have to be 100% frictionless; this condition does not exist in any mechanism with moving parts.)

Have your students research the topic of perpetual motion machines and share some of the more interesting ones with the class.

Have the students build and design a winch powered by an alternative energy source, such as water (from a faucet or hose) or wind (from a fan), and determine the work and power.

Language Arts

Challenge students to spend 10 minutes brainstorming a list of as many different situations they have seen of winches being used in everyday life. Ask each student to select one item and write a brief description of it and how it relates to the Control System activities.

Social Studies

What are some energy sources that are about to be depleted? (These include the so-called fossil fuels of oil, coal, and natural gas.) What are some new energy sources that have yet to be utilized on a large scale? (These include solar power, heat from geothermal sources, tidal movement, and wind.)

Unit III
Current Events: Electricity Generation as a Study of Change

Objective
The purpose of this unit is to introduce students to the concept of electricity generation. After working through the activity in this unit, each student will be able to demonstrate and explain how to generate current electricity.

Activity Listing
 Exploration 1 Explore the motor as a generator

Background Information
When electrons are forced to move through materials called conductors (such as metal wires) current electricity is produced. Current electricity is one of the most useful forms of energy today.

Current electricity is classified as alternating current (AC) or direct current (DC). In an AC circuit, the direction of the current changes or alternates direction rapidly. The electricity supplied to our homes is AC. In a DC circuit, the direction of the current remains constant. A battery supplies DC electricity.

The electricity that operates the motor, lamp, and sound generator in the Control System building set is DC. The alternating current supplied by the electrical outlet in your room is changed to DC by the transformer that is connected to the interface box.

Motors, lamps, and sound generators are devices that change electrical energy into some other form of energy. Electrical energy is changed into sound energy by the sound element, into light energy by the lamp, and into mechanical (or kinetic) energy by the motor.

Students can generate electricity by turning the axle of the LEGO® motor. This happens because the wire windings on the rotor pass near permanent magnets in the motor housing. The motion of the wire causes the magnetic field to exert a force on electrons in the wire. The force makes the electrons move along the wire, resulting in DC electricity.

Hints and Tips
Successful electricity generation depends on how fast the motor axle is turned. Students should focus on gearing up mechanisms for maximum turning speed.

Electricity Generation Exploration 1
Turn It On

Goal - Students will learn that kinetic energy can be turned into electrical energy and that electricity can be generated by turning the shaft of an electric motor.

What To Do

Divide students into teams of two or three. Assign each team to a computer equipped with the Control System materials:

- Control Lab software - installed on hard disk
- Interface box, cable, and transformer - connected to computer
- Simple Control building set (item #9702)
- One angle sensor and one light sensor

Ask students to clip both studs of the lamp to the metallic section on the bottom of the motor so that the lamp bulb faces the same direction as the motor shaft. Challenge students to twirl the motor shaft with their fingers and watch the lamp bulb. If they twirl the shaft fast enough, they will see a brief flash of light. This means that the motor is generating electricity.

Give students the opportunity to explore other ways to turn the motor shaft. Perhaps they can discover a way to turn it faster or for a longer time. They might try wrapping a length of string around the motor shaft and pulling on it suddenly, for example.

Ask questions to help them discover that they are changing kinetic energy (energy of their motion) into electrical energy.

Copy and distribute Handout 8 on electricity generation. (See copymaster on page 77.)

Handout Tips

In step 1 of the handout, note the gearing up mechanism. If students build the model in the drawing, the 24-tooth gear on the same axle as the rear wheels meshes with an 8-tooth gear above it. Each time the wheels go around once, the 8-tooth gear goes around three times (24/8 = 3). The 8-tooth gear is on the same axle as a 24-tooth crown gear which, in turn, drives an 8-tooth gear on the motor shaft. Each time the crown gear goes around once, the 8-tooth gear on the motor shaft goes around three times (24/8 = 3). Thus, each time the wheels go around once, the motor shaft goes around nine times (3 times 3).

In step 2, when students roll their vehicle along the floor, the lamp should light up, regardless of which direction they roll their vehicles.

In step 5, students should realize that the brightness of the light (as reported by the light sensor) is a direct indication of the quantity of electricity being generated.

In step 7, students will see the readings for both the light sensor and the angle sensor change as they roll their vehicles back and forth.

In step 14, students should move their vehicle first in the direction which increases the angle sensor reading. Negative numbers from the angle sensor will not appear on the graph.

In steps 15 and 16, students should be aware of the cause and effect process they are graphing. When they move their vehicles, the turning of the wheels generates electricity to operate a lamp which, in turn, activates a light sensor. The lamp lights regardless of whether the angle sensor readings are increasing or decreasing.

Building Tips

Students should use a gearing up mechanism to increase the turning speed of the motor shaft. All axles must be supported securely.

Interdisciplinary Extensions

Mathematics

Discuss with students the relationship between the speed that the motor shaft is turned and the brightness of the light. In general, turning the motor shaft faster generates more electricity.

Challenge students to estimate the average speed of their vehicles while they are generating electricity.

Technology

Challenge students to design a generator with a hand crank and more gears. With such a device it is possible to generate electricity at a fairly even rate.

Suggest that student groups share motors so that they can build a motorized generator, with one motor turning another. What additional devices can be connected to the motorized generator?

Discuss with students the similarities and differences between motors and generators.

Ask students to report on possible future sources of electricity which do not use generators, such as solar cells.

Language Arts

Students can add text boxes to their project pages to describe graphs and other aspects of their generator activity.

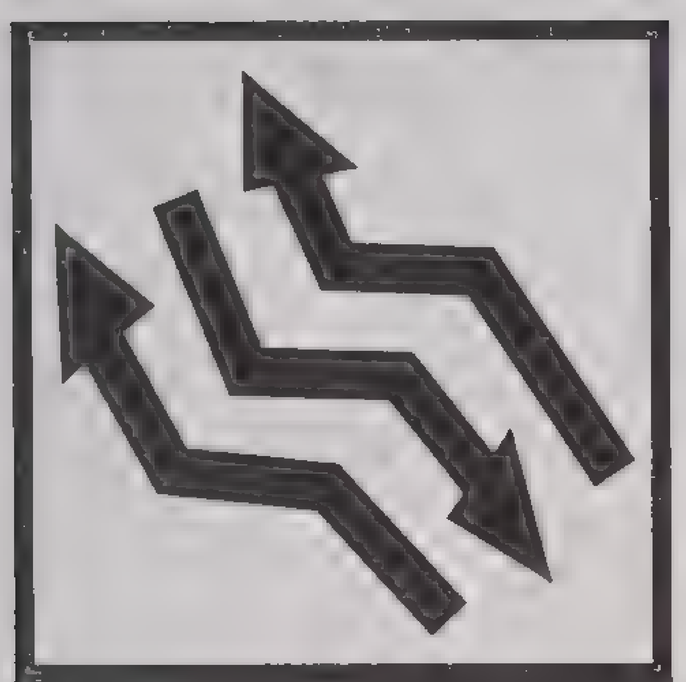
Ask students to write a short speculative paper that describes what life in the 20th century would be like if no electricity could be generated in any way.

Challenge students to communicate with each other using their generators. This may stimulate interest in the Morse code. Discuss how this process relates to difficulties experienced by people who cannot hear.

Social Studies

Ask students to research the historical debate on whether AC or DC electricity should be used for everyday power. Why did Thomas Edison favor DC, for example? Why was AC ultimately selected?

Handout Copymasters for Control System Activities



Motion as a Study of Change

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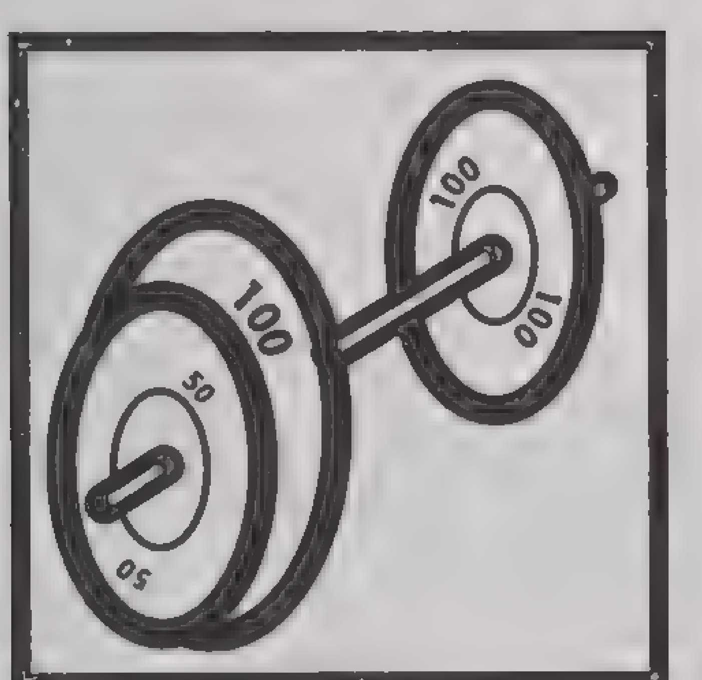

Work, Power, and Energy as a Study of Change

71 Exploration 1, Crank It Up
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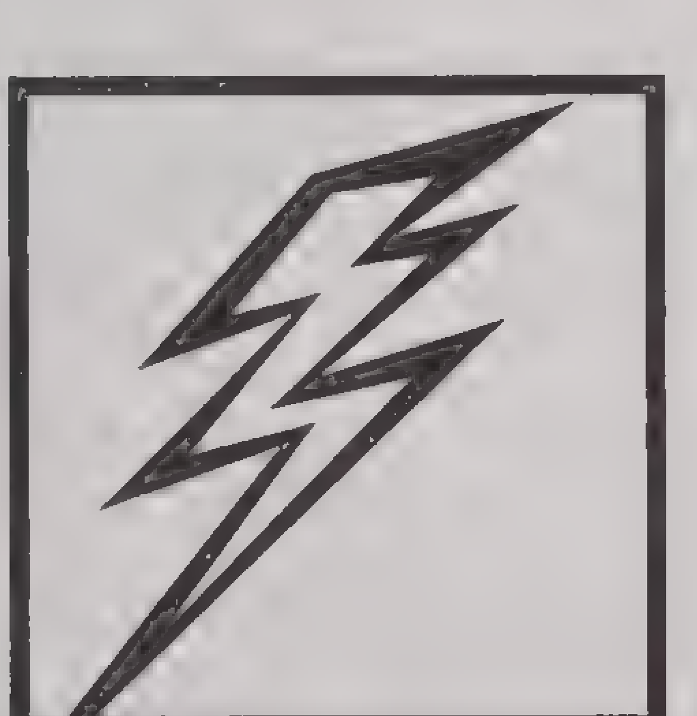


Electricity Generation as a Study of Change

77 Exploration 1, Turn It On

Names: **Date:**

Motion Exploration 1
A Matter of Procedure

You can always tell a computer, but you may not be able to tell it very much — unless you know how to write procedures (computer programs). In this activity, you will learn how to write simple procedures and make the computer carry them out. Follow the steps below. Pay particular attention to spaces when typing.

1. Connect the interface box to the computer. Turn on the computer and start up the Control Lab software. Click on the File menu and select New Project.

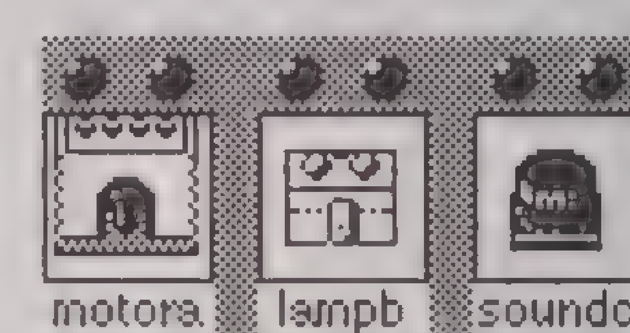
2. Connect the following elements to the interface box with connecting leads.

   motor .... output port A

   lamp .... output port B

   sound element ..... output port C

3. On the software Setup Page, drag motor, lamp, and sound element icons to ports A, B, and C to show how you connected them.



4. Type the following in the Command Center to verify that the motor goes on for 4 seconds. (Remember: 4 seconds = 40 tenths of seconds.)

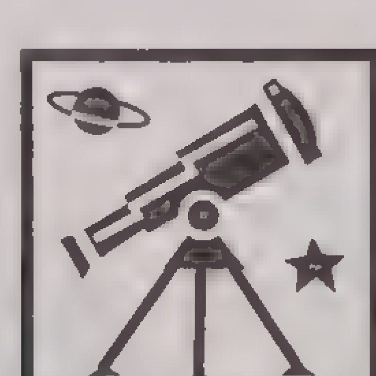
```
talkto "motora
onfor 40
```

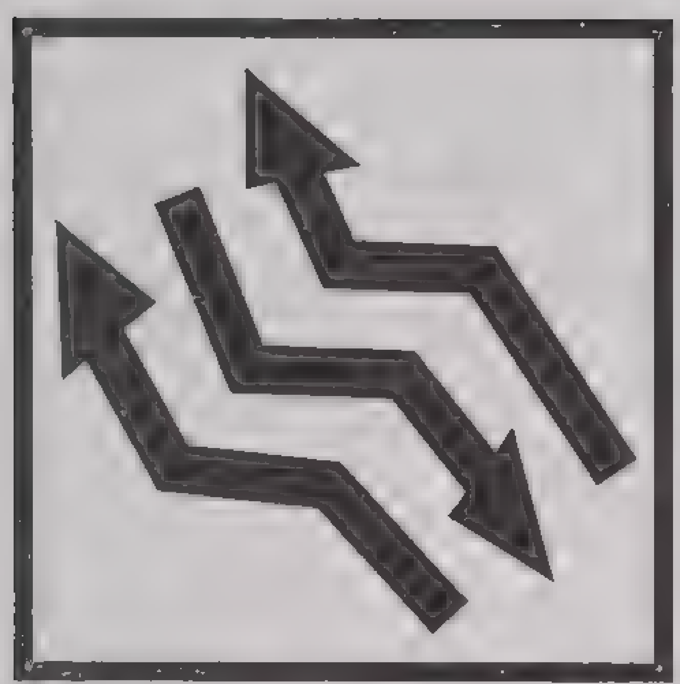
5. Click on the Pages menu and select Procedures. This brings you to the Procedures Page, where you will write your procedures. Notice the blinking cursor in the upper left corner.

6. Create a procedure called `turn` by typing the following in the Procedures Page. Press Return or Enter after each line.

```
to turn
talkto "motora
onfor 40
end
```

✏ **Note:**
Nothing should happen when you press Return or Enter while in the Procedures Page.





7 Click in the Command Center and type `turn`. When you press Return or Enter, the motor goes on for 4 seconds. The procedure behaves like a new command called `turn`.

8 Click in the Procedures Page beneath the end of the `turn` procedure and press Return or Enter a couple of times to make space for your next procedure.

9 Type a new procedure called `shine` to make the lamp light up for 2 seconds. Then run your new procedure by typing `shine` in the Command Center.

10 Now create a procedure called `beep` to turn on the sound element for 3 seconds. Run your `beep` procedure in the Command Center.

✏ **Note:**
Procedure names can be used as commands within other procedures, such as `action`. Procedures containing names of other procedures are called *superprocedures*.

11 Return to the Procedures Page and type in the `action` procedure . Notice that this procedure uses `turn, shine` and `beep` as commands.

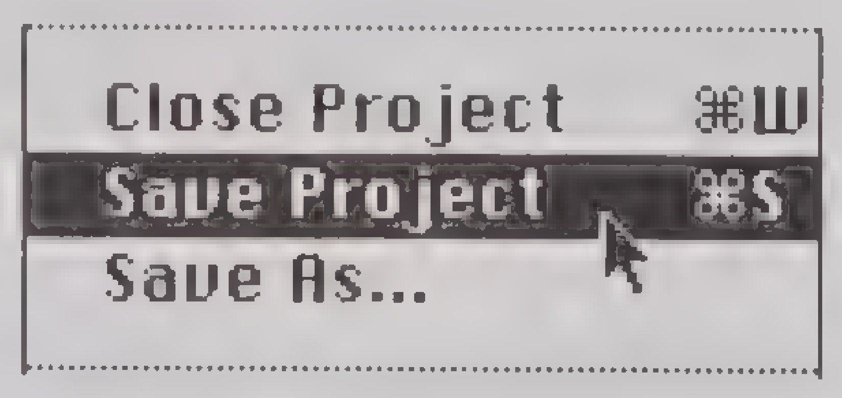
```
to action
turn
wait 30
shine
wait 10
beep
end
```

12 Run the `action` procedure in the Command Center.
What happens? ______________________________

13 Create and run one or more procedures of your own.

14 Type `printtext` in the command center to print out your procedures. Make sure your printer is connected to your computer and is turned on.

15 To save your procedures, click on the File menu and select Save Project.



16 Name your project Explore1 by typing `Explore1` in the "Save project as:" box in place of `Untitled`. Then click Save.

! **Now you can write a procedure to control the motor, lamp, and sound element.**

Summary

Procedures are typed in the Procedures Page. Instructions in a procedure are carried out when you type the procedure name in the Command Center. A procedure name is like a command.

To write a procedure, follow these steps.

1. Go to the Procedures Page.
2. Type the word `to` followed by a procedure name on the same line.
3. Type the instructions for the procedure beneath the first line.
4. Type `end` on a separate line.

To run your procedure, follow these steps.

1. Click in the Command Center
2. Type the name of your procedure and press Return or Enter.

To print out your procedures, follow these steps.

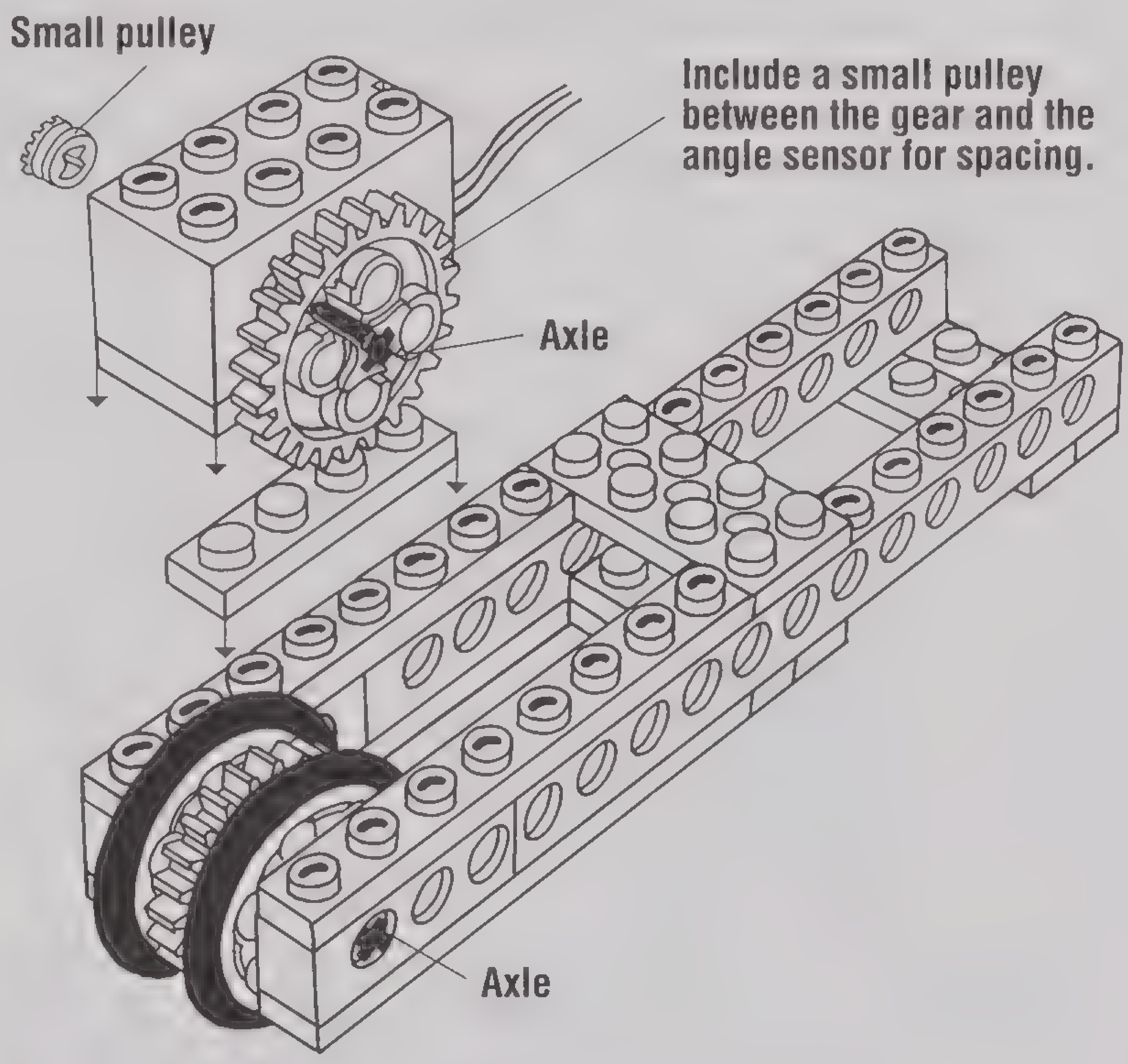
1. Make sure your printer is connected to your computer and is turned on.
2. Go to the Procedures Page.
3. Type `printtext` in the Command Center and press Return or Enter.

Names: **Date:**

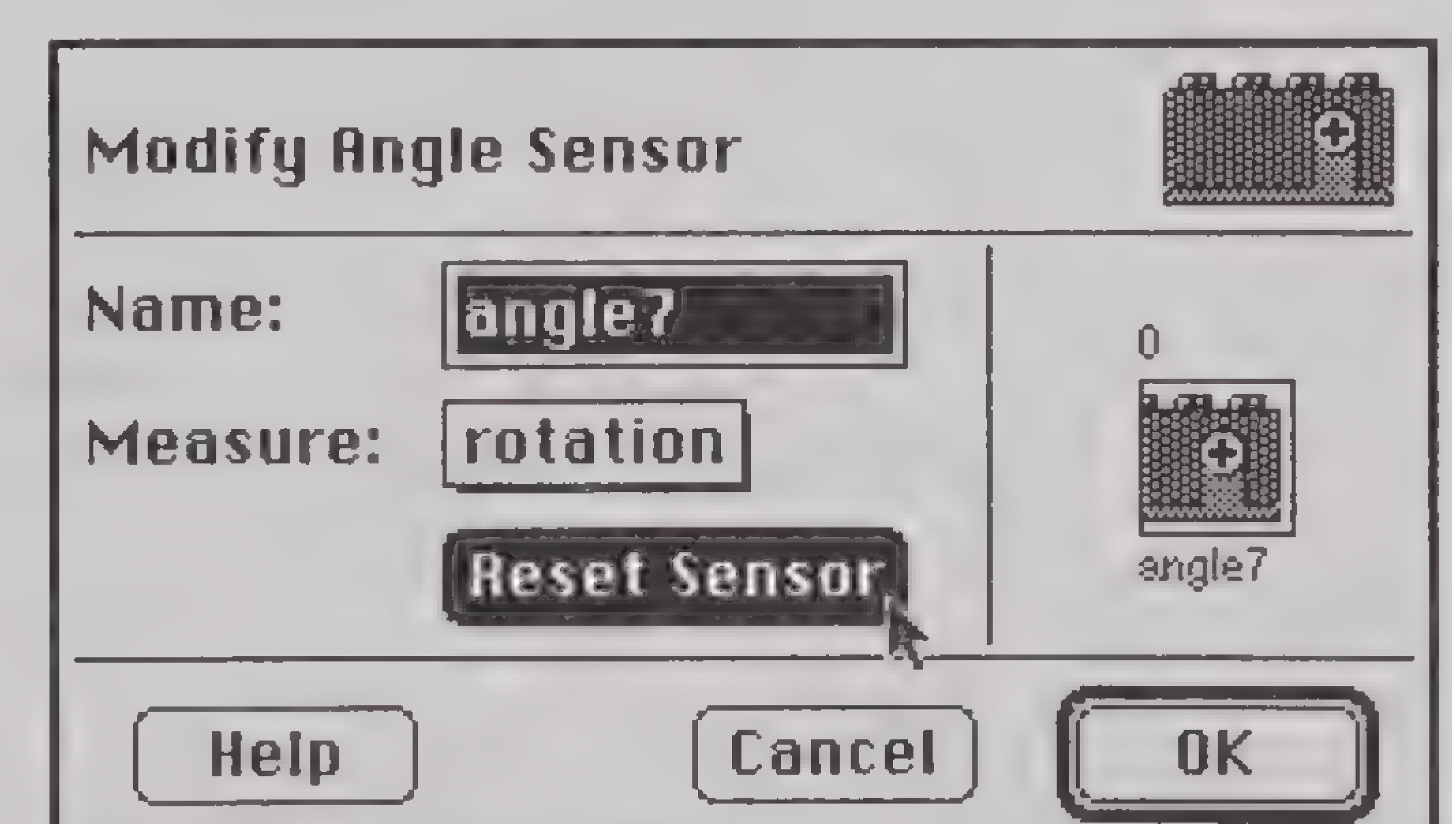
Motion Exploration 2 Trundle On

What is the distance around your head? How wide is your desktop? In this activity, you will build a trundle and then use it along with computer software to measure various distances.

1. Build a trundle of your own design or similar to the one shown below. The two gears should mesh firmly. Connect the angle sensor to input port 7.



2. Start up the Control Lab software, click on the File menu on the computer screen and select New Project.
3. Drag an angle sensor icon to input port 7 on the Setup Page.
4. Display the angle sensor dialog box by double clicking on the angle sensor icon on input port 7 on the Setup Page.



Angle Sensor Dialog Box

5. Reset the angle sensor value to zero by clicking Reset Sensor in the angle sensor dialog box.

6. With the angle sensor dialog box still on the screen, explore with your trundle by rolling it along your desktop, around your head, or along other distances.
What angle sensor reading do you obtain for one complete revolution of the wheel? ____________________
What is the reading when the trundle rolls 20 centimeters (8 inches)? ____________________
Click OK when finished.

7. Click on the Pages menu and select Page1. This takes you to a project page.

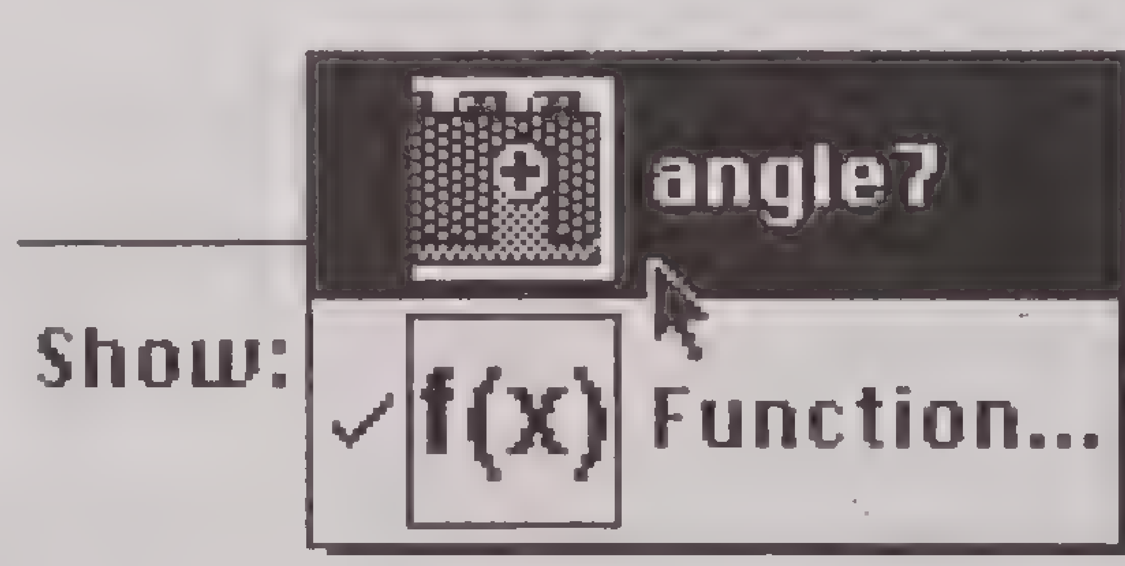
8. Make a monitor for your angle sensor on the project page. First, click on the monitor tool (third from the bottom) on the left of the project page. Then click in the project page to make a monitor.

Monitor Tool

Monitor

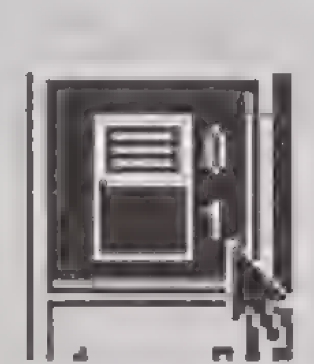
✏ **Note:**
Hold down the mouse button when you click on f(x).

9. Display the monitor dialog box by holding down the Shift key and double-clicking the monitor. Click on the f(x) in the Show: box and drag upward to select angle7, then release the mouse button. Click OK.



10. Roll your trundle and watch the number in the monitor change. The monitor displays the angle sensor reading.

11. Make a button to reset your angle sensor to zero. First, click on the button tool (second from the bottom) on the left of the screen. Then click in the project page to make a button.



Button Tool

Button

12. Hold down the Shift key and double-click the button to display the dialog box. Change the button type to "On" by clicking in the "On" button.

Type: ○ On/Off
◉ On

13. Click in the "Action: On" box and type `resetrotation 7`. Then click OK.

Action: On `resetrotation 7`

14. Roll the trundle around and observe how the reading in the monitor changes. Then click on the button to reset the angle sensor reading to zero.

15. Calculate a scale factor for centimeters to help measure distance.

a. Mark off a distance of 10 centimeters.

b. Place your trundle wheel on one distance mark.

c. Reset the angle sensor reading to zero.

d. Carefully roll the trundle along the distance.

e. Divide the 10 centimeter distance by the angle sensor reading.

Your scale factor for centimeters is:

$$\frac{10}{\boxed{}} = \underline{\qquad} \text{ scale factor}$$

angle sensor reading

16 Type the `trundle` procedure in the Procedures Page. The procedure calculates the distance your trundle rolls, using your scale factor. This distance is the product of the scale factor times the angle sensor reading. Type your scale factor in place of the blank.

```
to trundle
make "distance   ____ * angle7
show sentence :distance [centimeters]
end
```

17 Return to the project page. Mark off an unknown distance on a separate piece of paper. Reset the angle sensor to zero and roll the trundle along the unknown distance. Then type `trundle` in the Command Center to calculate the distance. Record the result. Repeat your measurement of the same unknown distance twice more. Reset the angle sensor to zero before each trial.

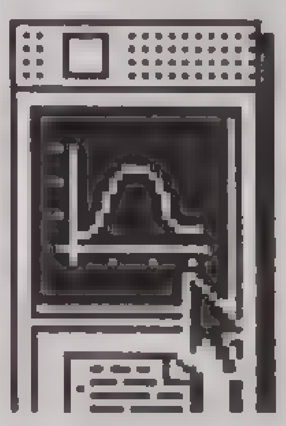
Trial	Distance (cm)
1	
2	
3	

18 Calculate the average value of the unknown distance.
Result: ______________________________

19 Measure the unknown distance with a centimeter scale to confirm your calculation. Result: ______________________________
Discuss reasons for any difference.

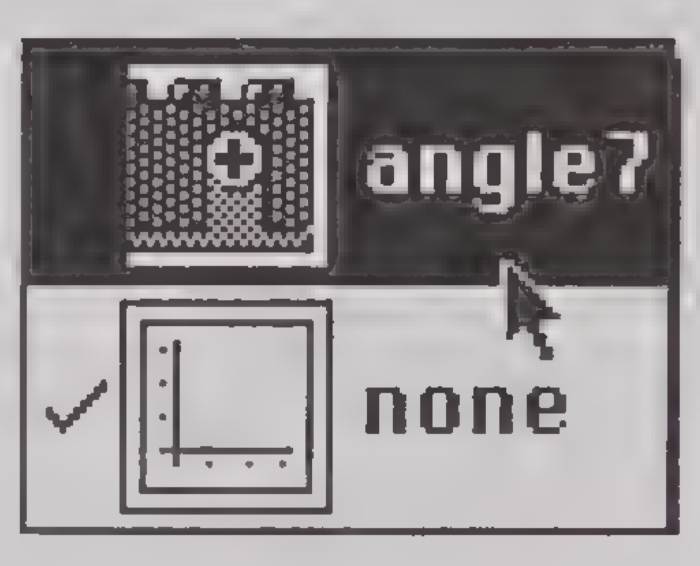
20 Measure other longer and shorter distances. Can you find any pattern to your results?

21 Set up a graph for your angle sensor on the project page. First, click on the graph tool on the upper left of the project page. (The graph tool has a small graph with axes.) Then click in the project page to set up a graph.

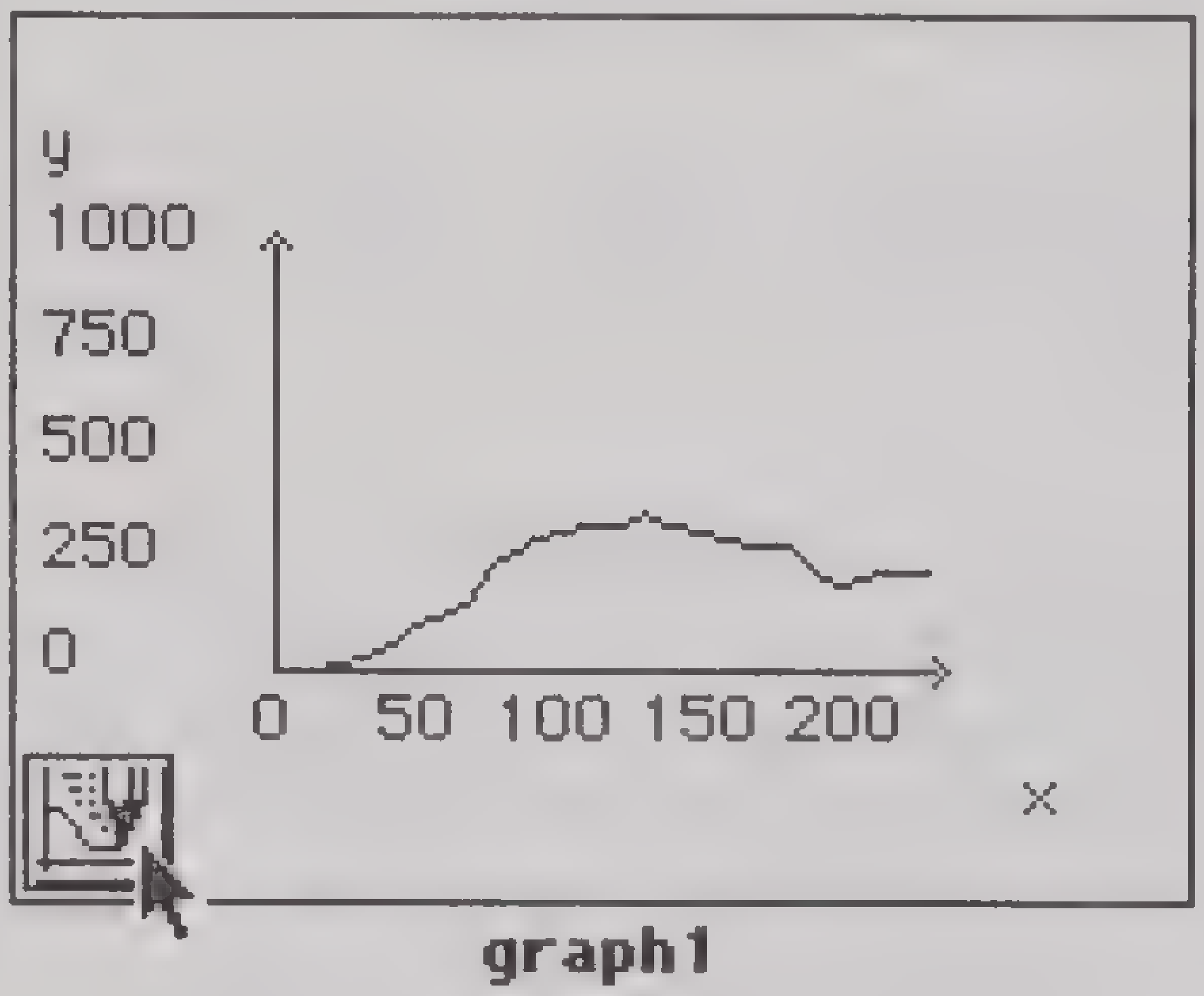


Graph Tool

22 Display the graph dialog box by holding down the Shift key and double-clicking the graph. Click on Sample 1 and select `angle7`. Then click OK.



23 Click on the graphing box in the lower left corner of your graph to start the graphing. Roll your trundle over a long distance, then back. Notice how the graph develops. To stop the graphing, click the graphing box once more.



What is being graphed along the y-axis? ______________________

What is being graphed along the x-axis? ______________________

24 Save your project. Click on the File menu and select Save. Type in a project name, such as `Explore2`, and click Save.

Now you can measure distance with a trundle using an angle sensor and computer feedback.

Names: Date:

Motion Exploration 3
Time Flies

Do you have good reflexes? How quickly can you react to a sound? In this activity, you will measure your reaction time using a light sensor and your Control Lab software.

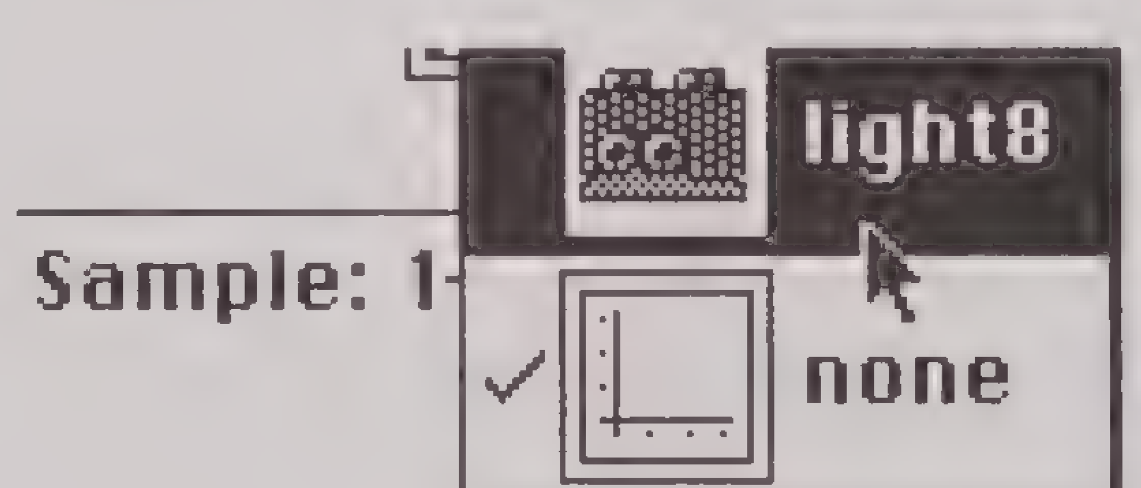
1. Start up the Control Lab software. Click on the File menu and select New Project.

2. Install the sound element on output port C and drag a sound element icon to port C on the Control Lab software Setup Page.

3. Connect the light sensor to input port 8 on the Control Lab interface box and drag a light sensor icon to port 8 on the Control Lab software Setup Page.

4. Explore the light values in the room by moving the light sensor around. Note how the sensor value above port 8 on the Setup Page changes as you point the sensor in different directions.

5. Now graph the readings of the light sensor. Here is how. Go to the project page and set up a graph to record the light sensor reading. (You may wish to refer to steps 21-23 from Exploration 2, Trundle On.) In the graph dialog box, select the light8 sensor in the Sample 1 box so that the light sensor readings will be used for the graph.



Change the Interval from 10 to 1. This sets up the graph to plot a point every tenth of a second.

While still in the graph dialog box, click on the small graph above the word "Points:". A smaller dialog box appears. In the smaller dialog box, change the Y-Max value to 100 because the light sensor is set up to report numbers between 0 and 100.

Click on OK in each box until you are back to the project page.

6. Click on the small icon at the lower left corner of the graph to start recording the values from your light sensor. Observe the graph as you move the light sensor toward light and toward dark areas, and as you cover and uncover the light sensor. Click on the small graph icon once more to stop the graphing.

7. Identify on your graph when you covered the light sensor and when you turned it toward bright and dark objects.

8. Slide a parabolic reflector over the lamp bulb. Connect the lamp to the test port on the interface box using a connecting lead. This turns on the lamp.

9. Using a few yellow LEGO® plates, build separate bases for the light sensor and the lamp. Place them facing each other about 5 centimeters apart so that the light shines directly into the light sensor.

10. Record the sensor reading when it is pointed directly at the lamp ____ and when you block the light beam to the sensor with your finger ____. (Do not place your finger on the sensor to block the light.)

11. Go to the Procedures Page and type in the `reaction` procedure below. There is no space in `resett1`, `light8`, or `timer1`.

```
to reaction
wait 30 + random 100
talkto "soundc on
resett1
waituntil [light8 < 60]
make "time  timer1 / 10
show sentence :time [seconds]
off
end
```

12. Test your reaction time. Point the light sensor toward the lamp and type `reaction` in the Command Center. Wait until you hear the sound element. Then block the light to the light sensor with your hand or a finger as quickly as possible. The computer shows your reaction time in seconds in the Command Center.

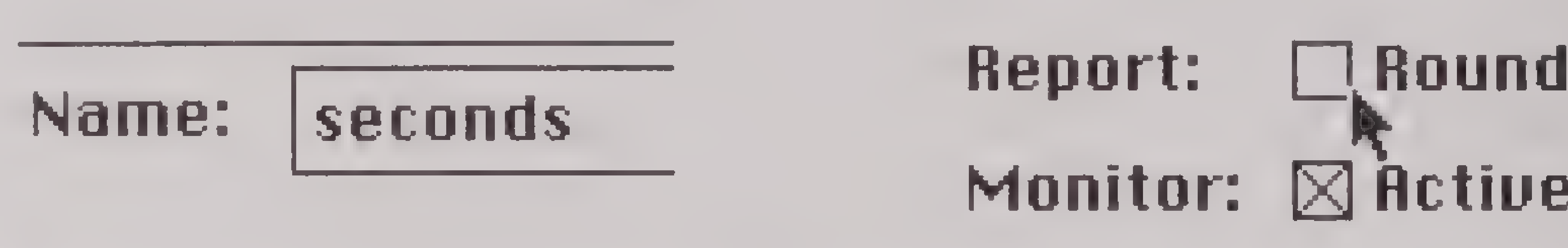
13 Record your reaction time on a separate piece of paper, and repeat at least three more times. Calculate the average value of your reaction time. What things might you do to improve your reaction time?

14 Make a monitor to display your reaction time on the Page1 project page. First, click on the monitor tool (third from the bottom) on the left of the project page. Then click in the project page to make a monitor.

Monitor Tool

Monitor

15 Display the monitor dialog box by holding down the Shift key and double-clicking the monitor. Change the name of the monitor to `seconds`. Also "deselect" the Round option so that the software will not round off your reaction time values.



16 Click once on the f(x) in the Show: box to display the Modify Monitor Function box. In the box, type `:time` and click OK until you are back at the project page. From now on, each time you run the `reaction` procedure, your reaction time is displayed in the `seconds` monitor as well. Try it!

17 Explore your reaction time with your hand in a starting position 30 centimeters away. Calculate the speed of your hand. Compare your speed with that of your teammates. What patterns do you see for various distances?

18 Your lamp and light sensor can work together for many other purposes as well. One use might be as a *photogate timer* at the finish line of a race. What other uses can you find for your device?

19 Save your project. Click on the File menu and select Save. Type in a project name, such as `Explore3`, and click Save.

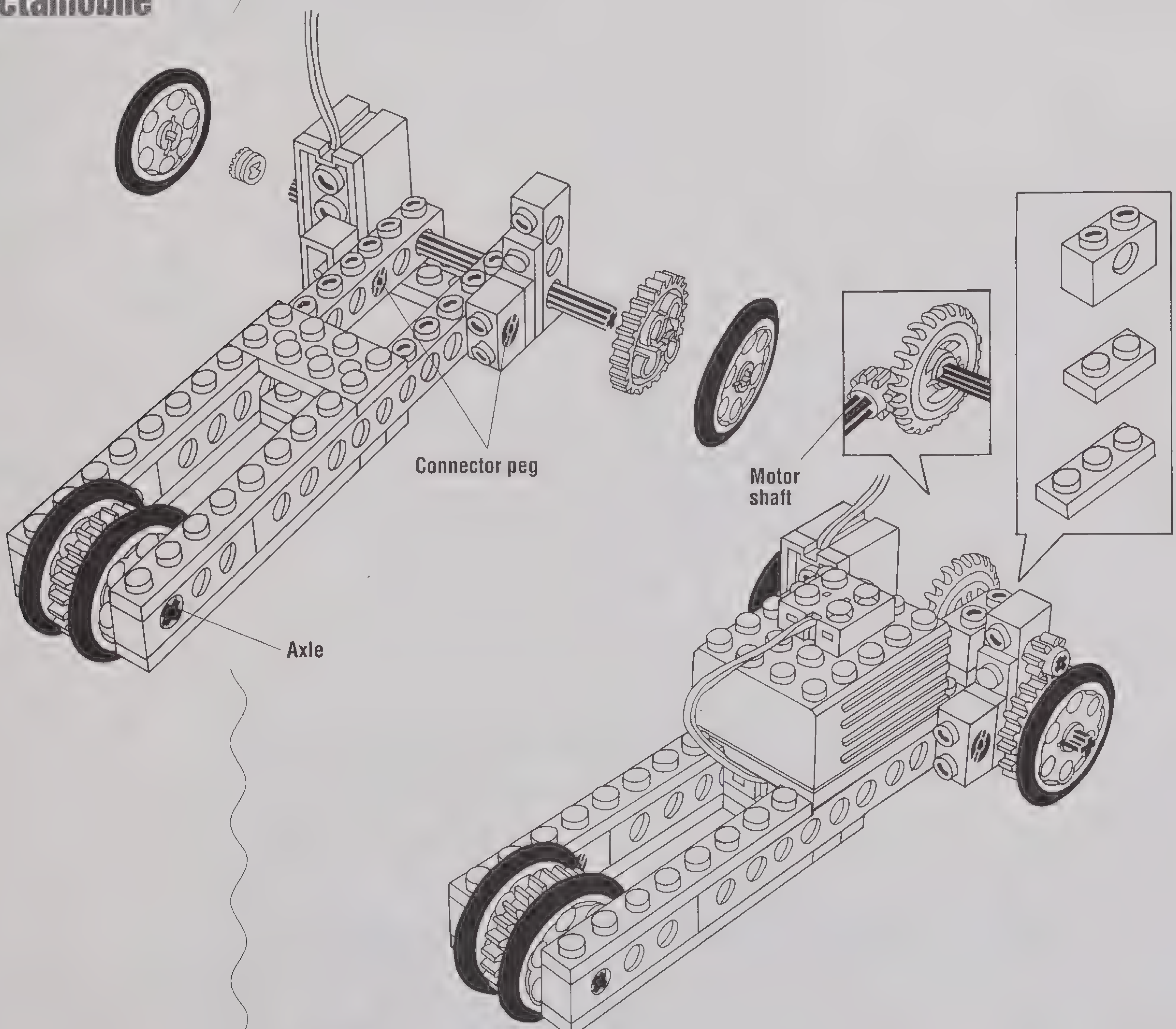
Now you can measure time using the light sensor.

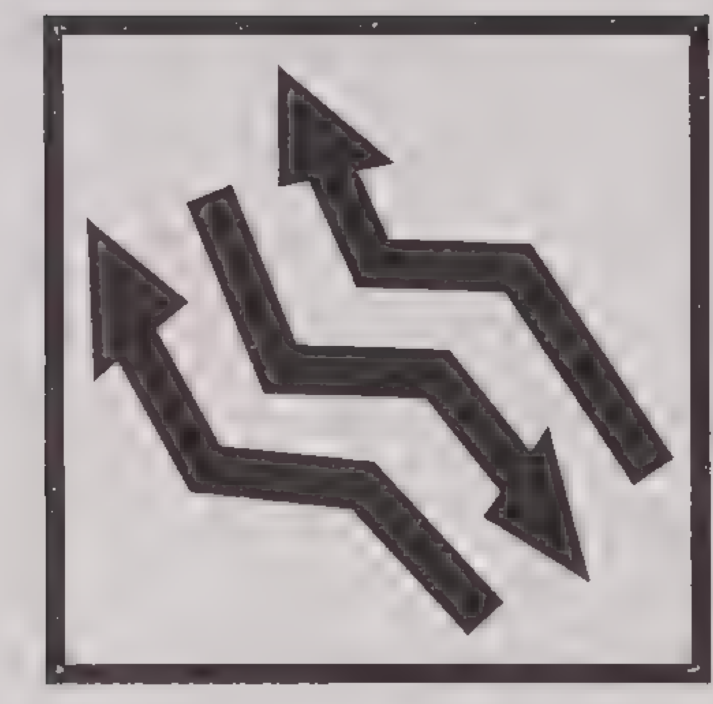
Names: **Date:**

Motion Exploration 4 The Dactamobile

Have you ever wondered how to measure speed? Now is your chance to find out! In this activity, you will build a motorized vehicle model and find out its average speed.

1. Build a motorized Dactamobile that includes an angle sensor. You may wish to build a model of your own design or similar to that shown below. Connect the angle sensor to input port 7 and the motor to output port A.





2. Start up the Control Lab software, click on the File menu on the computer screen and select New Project.

3. Drag the motor and angle sensor icons to the appropriate ports on the Setup Page. Click on the motor buttons on the Setup Page to see which way your Dactamobile has to travel for the angle sensor readings to increase.

4. Find your scale factor as you did with your trundle. ______ (See Exploration 2, Trundle On.)

5. Type the `find.speed` procedure in the Procedures Page. The procedure calculates the average speed of your model over a period of time. Type your scale factor in place of the blank.

```
to find.speed :seconds
resetrotation 7
talkto "motora
setpower 4
onfor :seconds * 10
make "distance ____ * angle7
make "speed :distance / :seconds
show sentence :speed [centimeters per second]
end
```

6. Explore whether the speed of your Dactamobile is the same for different times. For a run of 3 seconds, for example, type `find.speed 3` in the Command Center and press Return or Enter. Record the speed. Try other times with the `find.speed` procedure. What is the fastest and the slowest speed you obtain?

Trial	Time (s)	Speed (cm/s)
1		
2		
3		

7. Now determine the speed of your Dactamobile another way. Set up a photogate timer using the light sensor and the lamp with a parabolic reflector. Measure the distance from the start line to the finish line at the photogate with a meter stick. Measure the time of travel by having the Dactamobile block the light beam of the photogate timer to stop the clock. The `find.time` procedure sends the Dactamobile from the starting line to the photogate and then displays the time in seconds for the vehicle to travel the distance.

```
to find.time
resett1
talkto "motora
on
waituntil [light8 < 60]
make "time timer1 / 10
show sentence :time [seconds]
off
end
```

8. Place your Dactamobile on the starting line facing in the direction of the photogate timer. Type `find.time` in the Command Center. Then divide the measured distance by the time reported from the `find.time` procedure to calculate the average speed. Repeat for two more trials.

Trial	Distance (cm)	Time (s)	Speed (cm/s)
1			
2			
3			

9. Compare the Dactamobile speeds from steps 6 and 8, and discuss any differences.

10. Save your project.

Now you can find the speed of a model vehicle by measuring distance and time.

Names: **Date:**

Motion Investigation 1
Robotrike and Dactasaur

How fast does a vehicle go? What about a walking robot? Here is your chance to find out.

1. Build the Robotrike or the Dactasaur following the 9702-3 or 9702-4 building instructions. Connect the motor to port A on the interface box.

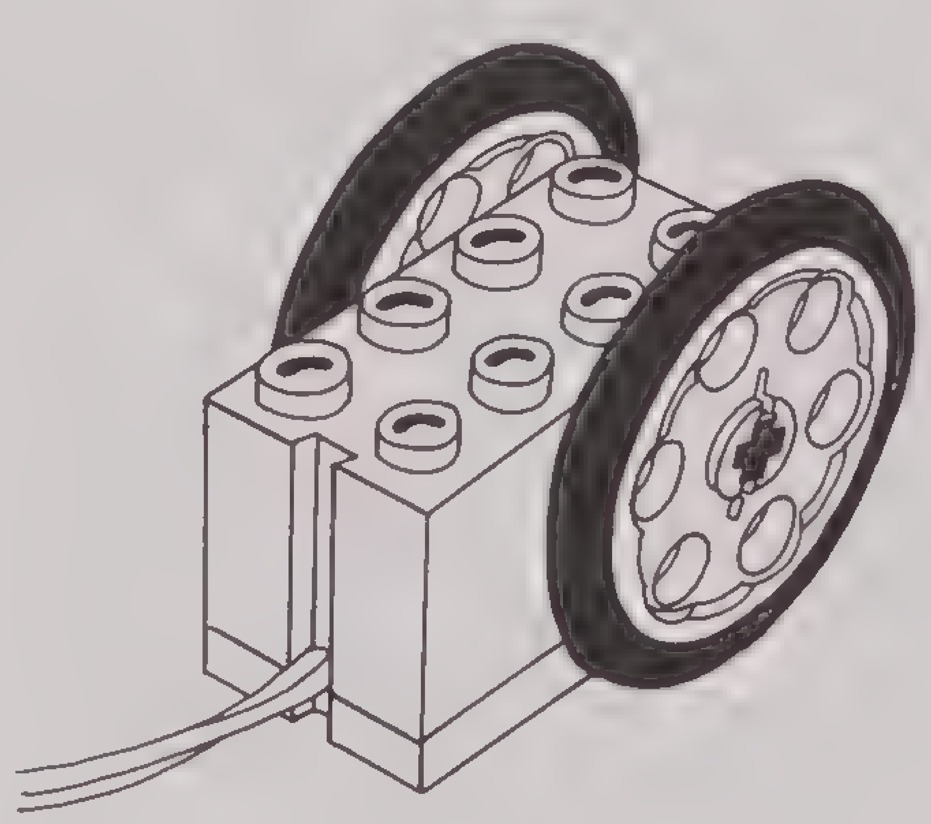
2. Start up the Control Lab software. Click on the File menu and select New Project. Place the motor icon on port A on the software Setup Page.

3. Investigate the motion of your Robotrike or Dactasaur by typing in the Command Center. The `rd` command might be helpful.

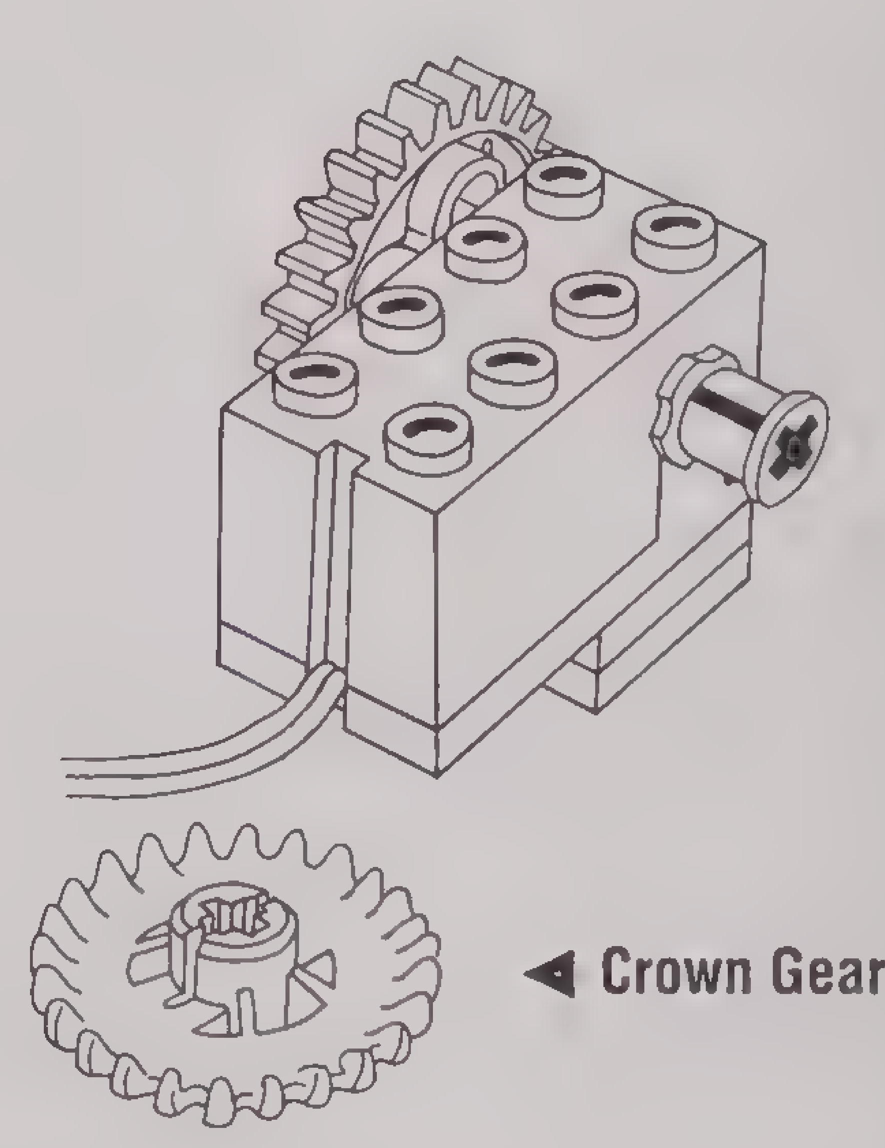
4. Find the average speed of your Robotrike or Dactasaur without using any sensors.

   Average speed _______

5. Add the angle sensor to your Robotrike or Dactasaur. Use the drawings below for ideas.



Place the angle sensor beneath the Dactasaur tail. Caution: the tail may rise up slightly as the Dactasaur walks. Keep the tail pushed down.



Replace the small pulley wheel on the top of the Robotrike with a crown gear. Mount the angle sensor next to it.

6. What is the scale factor for your angle sensor connection? _____

7. Find the average speed of your Robotrike or Dactasaur using information from the angle sensor. You may wish to use the `find.speed` procedure or write a procedure of your own. The first blank is for a number between 1 and 8 to set the motor speed. The second blank is for your scale factor.

```
to find.speed :seconds
resetrotation 7
talkto "motora
setpower ___
onfor :seconds * 10
make "distance  ___ * angle7
make "speed :distance / :seconds
show sentence :speed [centimeters per second]
end
```

Average speed ______

8. Find the average speed of your Robotrike or Dactasaur using a photogate timer. If you built a Dactasaur, use the lamp from your model. You may wish to use the `find.time` procedure or write a procedure of your own.

```
to find.time
resett1
talkto "motora
on
waituntil [light8 < 60]
make "time timer1 / 10
show sentence :time [seconds]
off
end
```

Average speed ______

9. Discuss any differences between the speed you found in steps 4, 7, and 8.

10 Work on one or more of the following suggestions.

a. Write procedures to turn the Robotrike and to make it go forward. The `setright` command prepares the motor to turn in a particular direction, while the `setleft` command prepares it to turn in the opposite direction. Here is an example in which the direction for `setright` happens to make the Robotrike turn.

```
to turn :time
talkto "motora
setright
onfor :time
end
```

b. Change the speed of your models using the `setpower` command. What new speeds do you obtain?

c. On the Page1 project page, set up a control center with buttons to make your model move and a slider to control the speed. Here is an idea for a button dialog box. The setright command makes the motor turn in a particular direction, while the setleft command makes it turn in the opposite direction.

```
Type:      (•) On/Off
           ( ) On

Action:    On   [talkto "motora setright on]
           Off  [talkto "motora off]
```

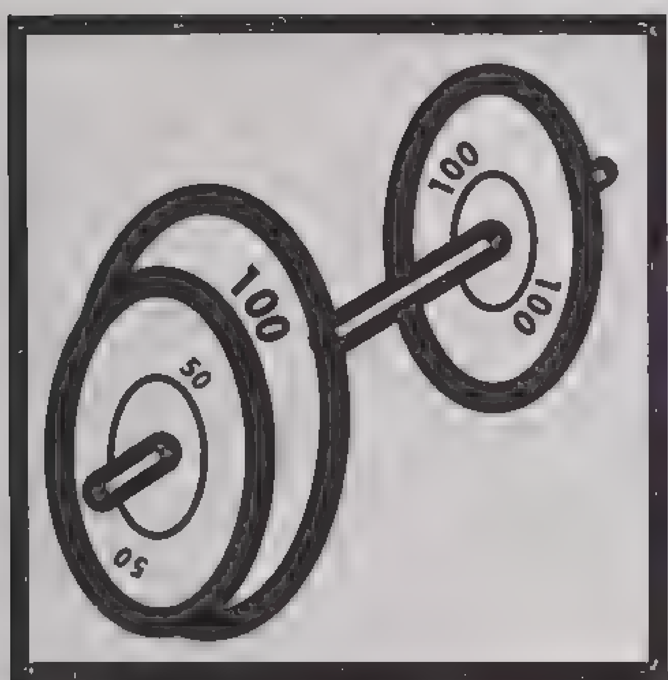
d. Graph the angle sensor on the Page1 project page as your model moves.

e. Write a brief description of your project in a text box on the Page1 project page and print it out.

11 Save your project.

! Now you can investigate the speed of a model vehicle using information from the angle sensor and the light sensor.

Names: **Date:**

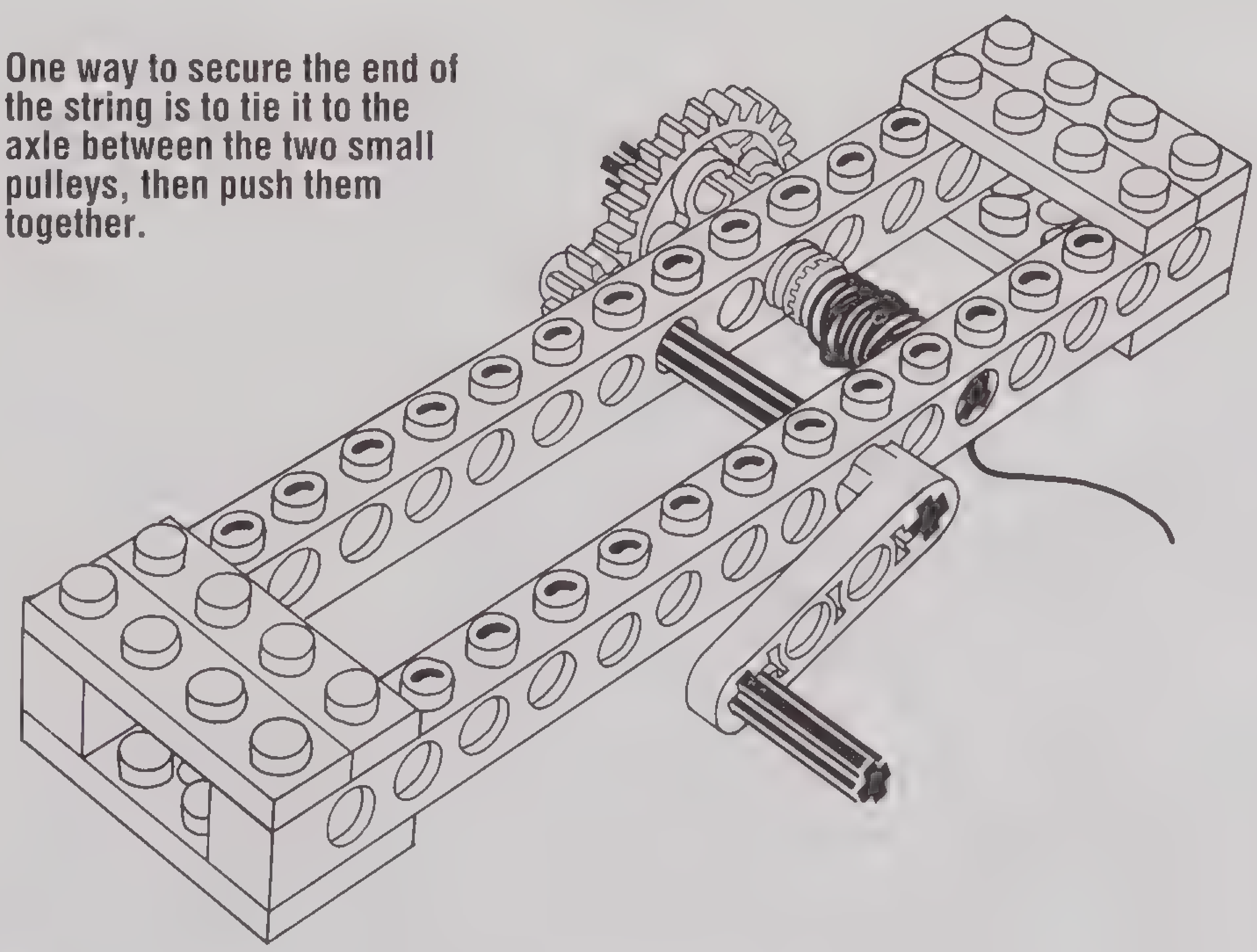


Work, Power, and Energy Exploration 1
Crank It Up

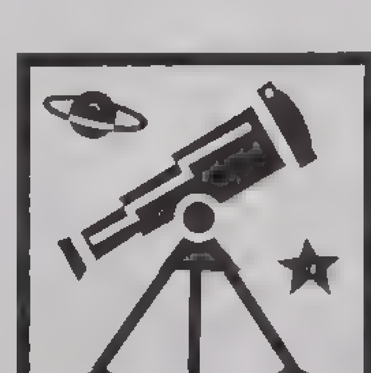
Much of our everyday work requires raising and lowering objects: cars are raised by hand-operated jacks, books are picked up and put down by hand, freight is loaded and unloaded using ropes and pulleys.

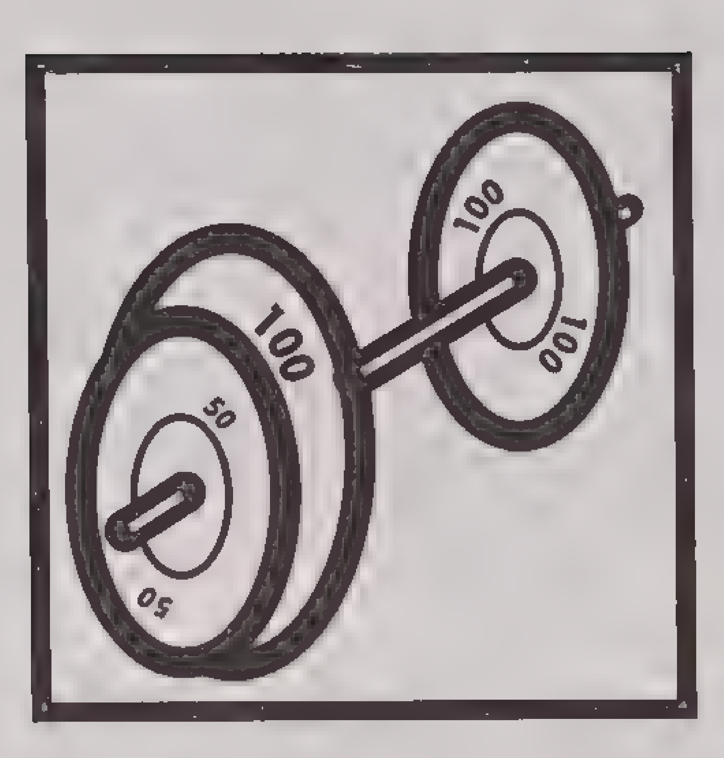
In this activity you will build and operate a lifting device, and use a computer to determine the work and power.

1. Build a hand-operated winch of your own design or similar to the one shown below. Explore how your winch can be used to raise various objects.

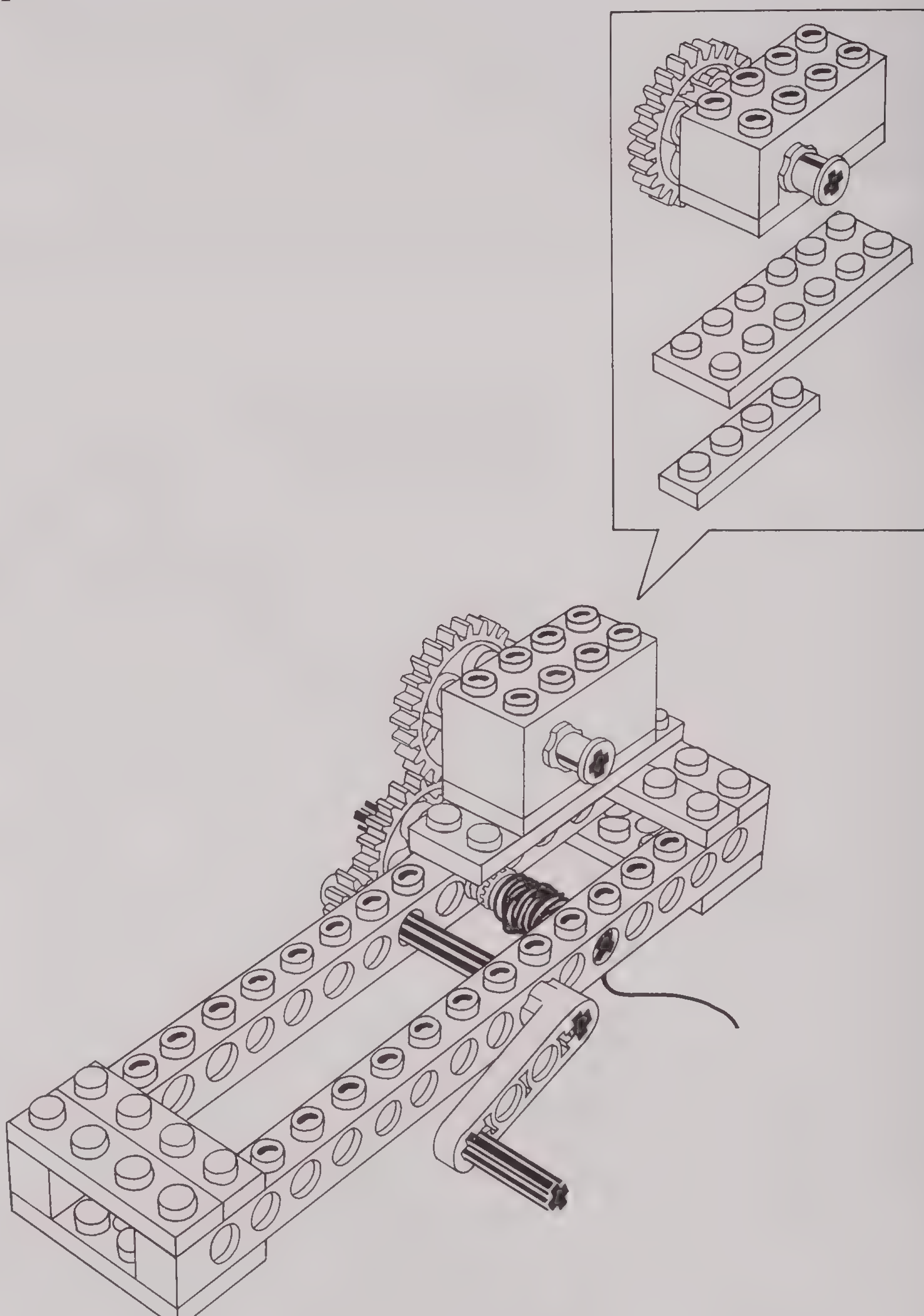


2. Measure the weight of a small object. _____ newtons.
3. Attach the object to the end of the string hanging from your winch.
4. Measure and record the vertical distance the object moves when the winch is cranked by hand. _____ meters
5. Measure and record the time required to move the object up the vertical distance. _____ seconds
6. Calculate the work _____ newton-meters and power _____ newton-meters / second



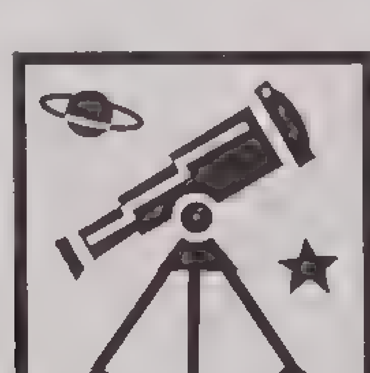


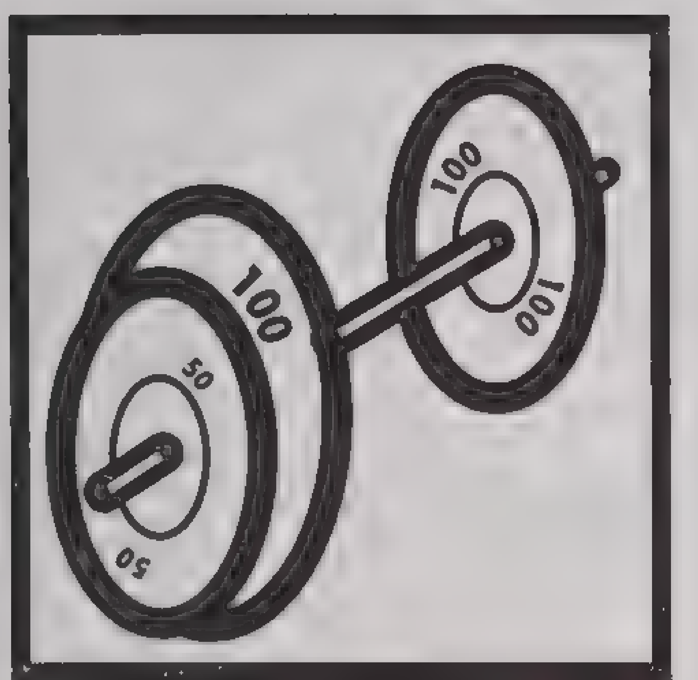
7. Add an angle sensor to your winch. Connect your angle sensor to port 7.



8. Start up your Control Lab software and open a new project. Drag an angle sensor icon to port 7 on the Setup Page.

9. On Page1 of your project, set up a button to reset your angle sensor to zero and a monitor to display the angle sensor reading.





10. Attach your object from step 2 to the end of the string, reset the angle sensor to zero, and raise the object 20 centimeters. What is the angle sensor reading when the object has been raised 20 centimeters? _____

11. The `lift` procedure uses the angle sensor to help you find the work and the power. Type the `lift` procedure in your Procedures Page. Put your 20-centimeter angle sensor reading from step 10 in the first blank. Put the weight of your object in newtons from step 2 in the second blank.

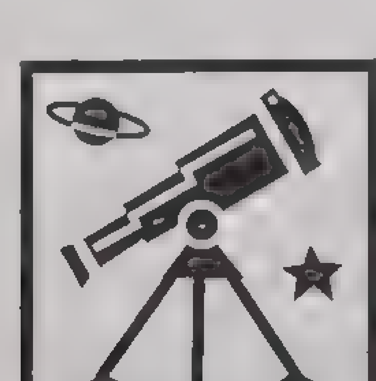
```
to lift
resetrotation 7
waituntil [(abs angle7) > 0]
resett1
waituntil [(abs angle7) > ____]
make "time timer1 / 10
make "work ____ * 0.20
make "power :work / :time
show sentence :work [newton-meters]
show sentence :power [newton-meters per second]
show sentence :power / 746 [horsepower]
end
```

12. To use the `lift` procedure, type `lift` in the Command Center and press Return or Enter. The procedure waits until you start turning your winch handle. When you have raised the object 20 centimeters, the procedure calculates your work and your power.

13. Compare your work and power calculations from step 6 and step 13. How do you account for any differences?

14. Print out your procedures using the `printtext` command. Save your project.

! Now you can find the work and power you produce with a winch.



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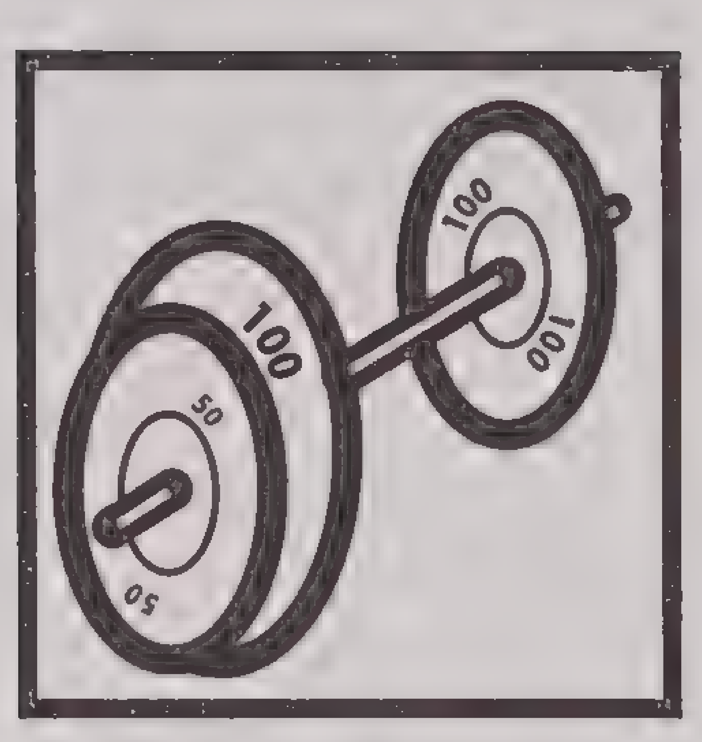
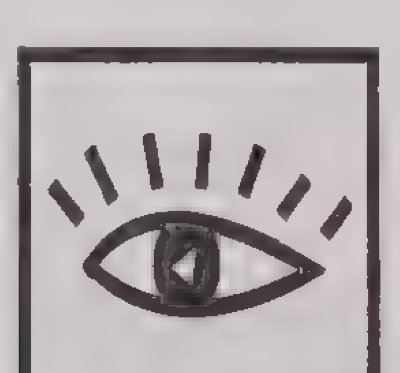


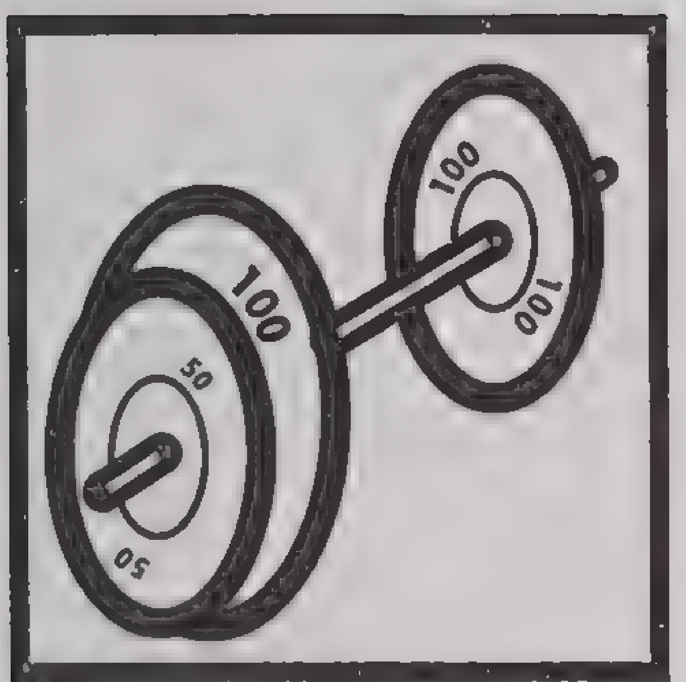
Work, Power, and Energy Investigation 1
Hi Ho Horsepower

One of the most commonly used motorized winches in this country is part of an elevator system. Here is your opportunity to build your own elevator! Then you can write a program to control its motion and to measure the work it accomplishes as well as its horsepower.

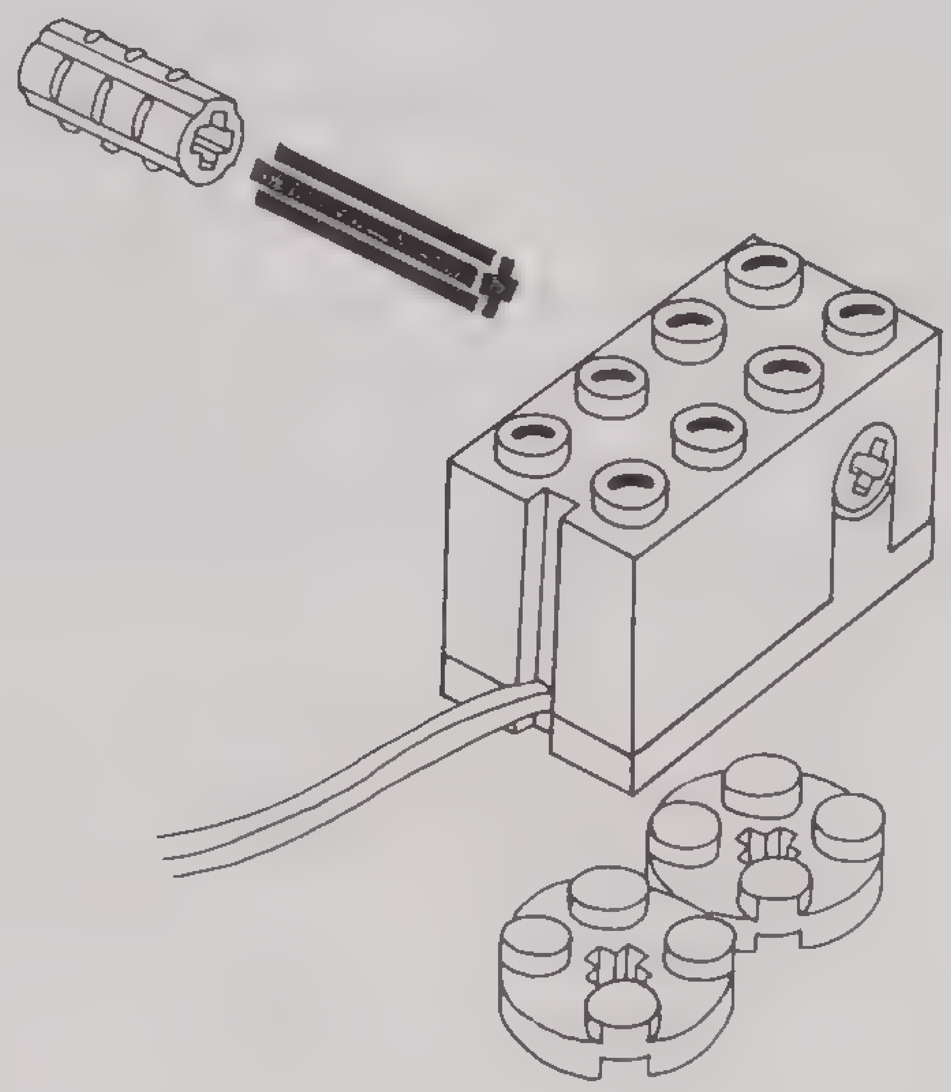
1. Build the Elevator following the instructions on Building Card 9702-2. *Stop at step 8* on the building card.
2. Measure the weight of the cage you built in step 8 of the building card. _____ newtons.
3. Place the cage in the elevator shaft and finish building the model.
4. Connect the motor to port A on your interface box. (You may wish to connect the lamp to port B and the sound element to port C as well.)
5. Start the Control Lab software and select New Project from the File menu.
6. Operate the elevator. You could click on the circles above the motor icon over port A on the Setup Page. You could type commands in the Command Center. Or, you could set up buttons on the Page1 project page.
7. How far up does the elevator travel from the bottom to the top of the shaft? _____ meters
8. How much work does the motor perform in raising the elevator from the bottom to the top of the shaft? _____ newton-meters
9. How much time does the elevator take to travel from the bottom to the top of the shaft? _____ seconds
10. What is the power used by the elevator?
    _____ newton-meters / second

    What is this in horsepower? _____ horsepower





11. Add the angle sensor to your elevator. The drawing below shows one way to attach the sensor to the end of the axle that winds the string.

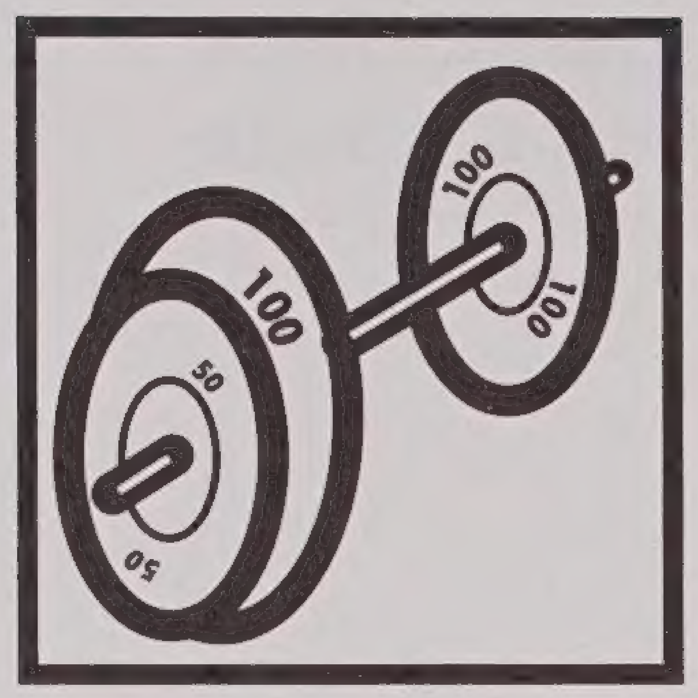


12. Move the elevator to the bottom of the shaft and set the angle sensor reading to zero.

13. Raise the elevator to the top of the shaft. What is the angle sensor reading? ______ Return the elevator to the bottom of the shaft.

14. Find the work and power values for the elevator using the computer and the angle sensor. You may wish to use the `goingup` procedure below or write a procedure of your own. Type the angle sensor reading at the top of the elevator shaft from step 13 in the first blank. Type the weight of the cage from step 2 in the second blank and the distance the cage travels from step 7 in the third blank.

```
to goingup
resetrotation 7
resett1
talkto "motora
setright  ———————————————— or setleft
on
waituntil [(abs angle7) > ___] —— angle sensor reading at top
off
make "time timer1 / 10
make "work ___ * ___   ———————— weight of cage * distance cage travels
make "power :work / :time
show sentence :work [newton-meters]
show sentence :power [newton-meters per second]
show sentence :power / 746 [horsepower]
end
```



15. Compare your results with those from step 10.
16. Weigh a small object and place it in the elevator cage. Repeat step 14 above, except change the weight of the cage in the `goingup` procedure to the weight of the cage plus the weight of the object. What are the results for the work and the power?
17. Save your project.

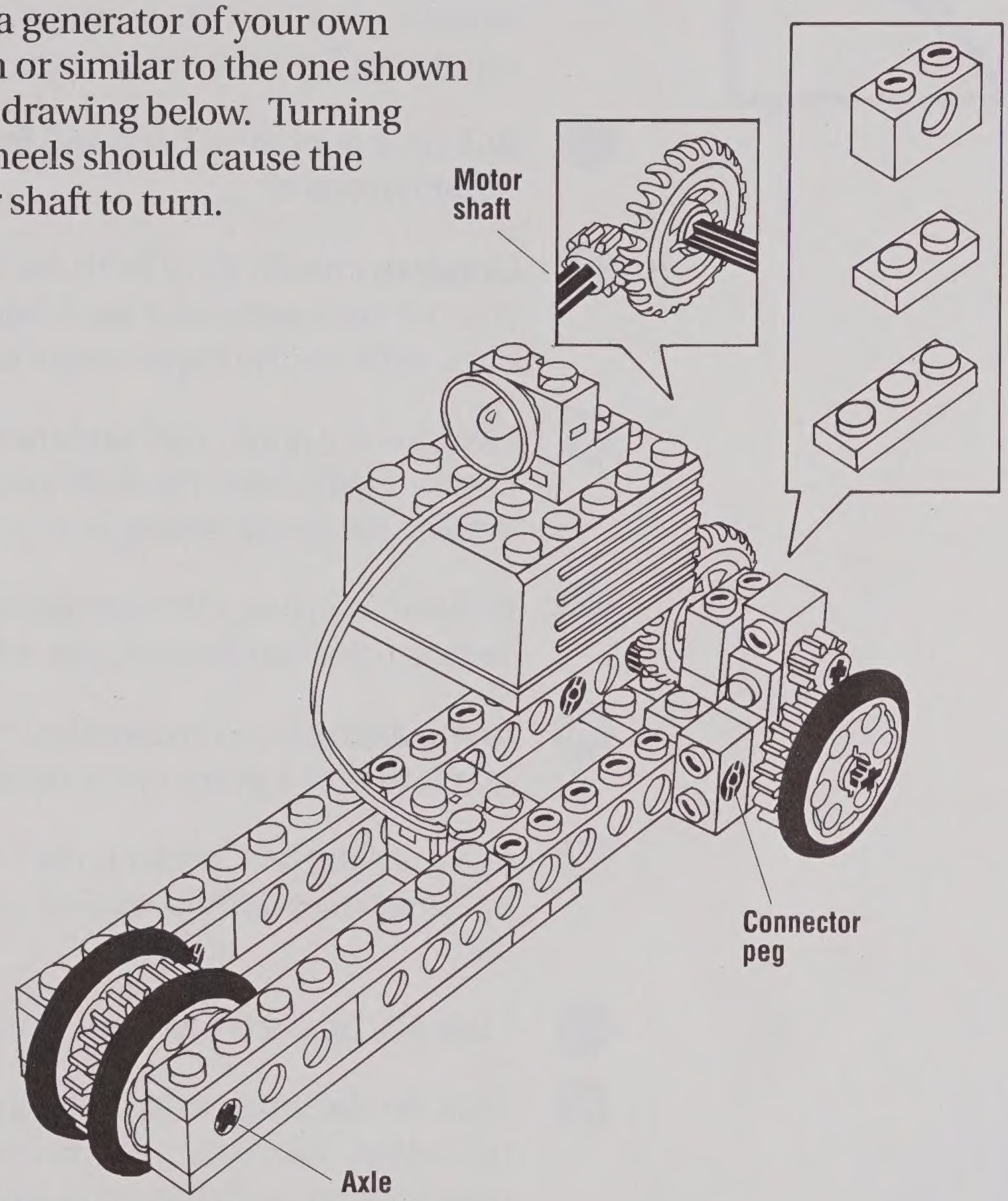
! Now you can find the work and power produced by a model elevator.

Names: **Date:**

Electricity Generation Exploration 1
Turn It On

Do you know where electricity comes from? Practically every electrical outlet can be traced to a generator. A generator changes mechanical energy into electrical energy, usually by turning a coil of wire inside a magnetic field. You can use a LEGO® motor to generate electricity.

1. Build a generator of your own design or similar to the one shown in the drawing below. Turning the wheels should cause the motor shaft to turn.



2. Roll your generator along the floor. What happens? ______________________________

3. Start up your Control Lab software. Click on the File menu and select New Project.

4. To your model, add a light sensor facing the lamp. Connect the light sensor to input port 8 on the interface box. Drag a light sensor icon to input port 8 on the Setup Page.

5. Operate your generator and observe the light sensor readings on the Setup Page.
What is the highest reading you can produce? ________________

6. Attach an angle sensor to your generator. Connect the angle sensor to input port 7 on the interface box. Drag an angle sensor icon to input port 7 on the Setup Page.

7. Roll your generator back and forth along the floor.
What happens? ________________________________

8. Graph the readings of both the light sensor and the angle sensor as you roll your generator back and forth along the floor. Here is how. First, click on the Pages menu and select the Page1 project page.

9. Click on the graph tool and then click in the project page to set up a graph. Hold down the Shift key and double-click the graph to display the graph dialog box.

10. In the dialog box, click on the Sample: 1 box and select the angle sensor. Click on the Sample: 2 box and select the light sensor.

11. In the dialog box, change the Interval from 10 to 1. This sets up the graph to plot a point every tenth of a second.

12. In the dialog box, click on the small graph above the word "Points:". In the smaller dialog box that appears, change the Y-Max value to 300.

13. Click OK on each box until you are back at the project page .

14. Click on the small icon at the lower left corner of the graph to start recording. Move the vehicle back and forth. Click on the small icon once more to stop the graphing.

15. Identify the graph for the light sensor and for the angle sensor.
What similarities do you observe? ________________________

16. What differences do you observe? ________________________

Optional: On the project page you may wish to create a button to reset the angle sensor. Also consider creating monitors for the angle sensor and light sensor values.

! Now you can generate electricity by turning the shaft of an electric motor.

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